12 NW MR 77-7

Laboratory Effects in Beach Studies

VOLUME I

Procedures Used in 10 Movable-Bed Experiments

by

Robert P. Stafford and Charles B. Chesnutt

MISCELLANEOUS REPORT NO. 77-7

JUNE 1977

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MR 77-7	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER (14) CERC-MR-77-7
4. TITLE (and Subtitle) (6) LABORATORY EFFECTS IN BEACH STUDIES. Volume I. Procedures Used in 10 Movable-Bed Experiments		5. TYPE OF REPORT & PERIOD COVERED (9) Miscellaneous Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Robert P. Stafford Charles B. Chesnutt		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CERRE-CP) Kingman Building, Fort Belvoir, Virginia 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS D31192
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center Kingman Building, Fort Belvoir, Virginia 22060		12. REPORT DATE (11) Jun 1977
		13. NUMBER OF PAGES 67 (12) 68p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

037 050

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Breakers	Wave envelopes
Coastal engineering	Wave generators
Currents	Wave height variability
Model studies	Wave reflection
Movable-bed experiments	Wave tanks

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Procedures developed and conditions existing during 10 experiments on Laboratory Effects in Beach Studies (LEBS) are contained in this volume as a convenient reference to the analyses of LEBS data reported in separate volumes. This report also serves as a procedural manual for a common type of coastal engineering experiment, and it describes the wave generators used to produce data published in previous reports by the Coastal Engineering Research Center (CERC). Special attention is given to the problem of running

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movable-bed experiments in outdoor facilities. Recordkeeping, construction of initial profile, water level control, wave height measurement, analysis of wave envelopes, ripple effects on profile accuracy, temperature measurement, and observation of breakers and currents are also discussed.

PREFACE

Ten experiments were conducted at the Coastal Engineering Research Center (CERC) from 1970 to 1972 as part of an investigation of the Laboratory Effects in Beach Studies (LEBS), to relate wave height variability to wave reflection from a movable-bed profile in a wave tank. The investigation also identified the effects of other laboratory constraints.

This report (Vol. I), the first of a series of eight volumes, documents the procedures used in the 10 movable-bed laboratory experiments. It also serves as a guide for conducting realistic coastal engineering laboratory studies. Volumes II to VII are data reports for each experiment; Volume VIII is a final analysis report. The work was carried out under the CERC coastal processes program.

This report was prepared by Robert P. Stafford, senior technician in charge of the experiments for the duration of the experimental program, and Charles B. Chesnutt, principal investigator from the beginning of the 1971 experiments through the completion of the program. Cyril J. Galvin, Jr., Chief, Coastal Processes Branch, was the principal investigator from the beginning of the experimental program through the planning of the 1971 experiments and provided general supervision thereafter.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 21 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

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LABORATORY EFFECTS IN BEACH STUDIES

Volume I. Procedures Used in 10 Movable-Bed Experiments

by
Robert P. Stafford and *Charles B. Chesnutt*

I. INTRODUCTION

This report (a) documents procedures necessary to conduct meaningful coastal engineering movable-bed laboratory experiments and model studies; (b) describes common procedures used in the Coastal Engineering Research Center's (CERC) investigation of Laboratory Effects in Beach Studies (LEBS) to conserve space and avoid repetition in reports on LEBS experiments; (c) provides a detailed record of LEBS experimental conditions for future analysis involving presently unrecognized parameters (e.g., tank length was not considered a significant parameter and often was not reported before the LEBS experiments); and (d) provides background on the operation of CERC's portable wave generators which have been used in other investigations (Savage, 1959, 1962; Fairchild, 1970a, 1970b; Galvin and Stafford, 1970).

A series of 10 experiments was conducted from 1970 to 1972 to define the amount of wave height variability due to wave reflection and variation in the reflection, and to measure the approach to "equilibrium" profiles for the wave and sediment conditions tested. The same sediment was used in all 10 experiments and the water depth and generated wave energy flux were held constant at 2.33 feet (0.71 meter) and 5.8 foot-pounds per second per foot (25.8 joules per second per meter), respectively. Of the 10 experiments, 5 were performed in a 6-foot-wide (1.8 meters) tank and 5 in a 10-foot-wide (3 meters) tank.

These experiments were conducted in relatively long, narrow wave tanks with the wave approach direction normal to the initial shoreline, and were expected to be two-dimensional. However, three-dimensional effects were observed in the profile development, the reflection envelopes, and the current patterns. These effects will be discussed in later reports.

Two experiments were conducted in 1970, one in each wave tank, with a wave height of 0.36 foot (0.11 meter), a wave period of 1.90 seconds, and an initial profile slope of 0.10. The initial test length (distance from the wave generator to the initial stillwater level (SWL) intercept) was 100 feet (30.5 meters) in the 6-foot tank, and 61.7 feet (18.8 meters) in the 10-foot tank. After 54 hours in the 6-foot tank and 62 hours in the 10-foot tank, the beach had eroded to the back of the tank. From then until the end of the experiments, sand was periodically added to the backshore to maintain an adequate supply. The two experiments were repeated in 1971 under the same conditions, except that additional sand was added which shortened the initial test length by 7 feet (2.1 meters) in both

tanks. Five experiments (two in the 6-foot tank and three in the 10-foot tank) were performed in 1972 with different wave energy densities but with the 1971 initial beach slope and initial test length. A sixth experiment was performed in 1972 in the 6-foot tank with a 0.05 initial beach slope and the 1971 wave energy density and initial test length. The test conditions are summarized in Table 1. The typical testing season was from May to December.

This report is part of a series of 8 reports on the 10 experiments, to consist of an experimental procedures report, 6 data reports, and a final analysis report. Each of the six data reports will cover conditions as identified in Table 1. The data in these reports are primarily intended to: (a) Relate temporal and spatial wave height variability to reflection from the movable-bed profile, (b) measure the approach of the profile to an equilibrium condition, and (c) determine as quantitatively as possible the effect of other laboratory constraints (e.g., water temperature, tank length and width, and initial slope) on the resulting laboratory profile.

This report documents the experimental procedures common to all the experiments, and alleviates the necessity of repeating these procedures in each of the six data reports. The data reports discuss the results from the experiments, and each report includes an appendix documenting the data collection and reduction procedures unique to the experiments.

Three earlier reports on these experiments are also documented in this report. Chesnutt, et al. (1972) discussed the development of the profiles in experiments 70X-06, 70X-10, 71Y-06, and 71Y-10. Chesnutt and Galvin (1974) analyzed the relationship between reflection variability and profile development in the same four experiments. Chesnutt (1975) analyzed other laboratory effects observed in experiments 70X-06, 71Y-06, and 72D-06.

II. GENERAL PROCEDURES

1. Facilities.

The Shore Processes Test Basin (SPTB), located in Washington, D.C., was a large, 3-foot-deep, outdoor, concrete basin (Figs. 1 and 2). Within the basin, pairs of 6- and 10-foot-wide wave tanks were constructed of aluminum panels (Figs. 3 and 4). The movable-bed profile occupied the left side (facing seaward) of each pair of tanks, and a 0.10 concrete slope occupied the right side. The concrete side was used for control purposes. The tank walls supported a manually propelled instrument carriage which was used for data collection along the full length of the tanks (see Figs. 3 and 4).

2. Experiment Schedule.

Each experiment was performed in a series of runs in either of two run sequences. The last column in Table 1 indicates the run sequence for each experiment; Table 2 indicates the cumulative test times at the end of

Table 1. Summary of experimental conditions.

Experiment[1]	Initial test length (ft)	Initial slope	Wave period (s)	Generated wave height[2] (ft)	Surveying sequence[3]
70X-06	100.0	0.10	1.90	0.36	A
70X-10	61.7	0.10	1.90	0.36	A
71Y-06	93.0	0.10	1.90	0.36	A
71Y-10	54.7	0.10	1.90	0.36	A
72A-06	93.0	0.10	3.75	0.31	B
72A-10	54.7	0.10	3.75	0.31	B
72B-06	93.0	0.10	2.35	0.34	B
72B-10	54.7	0.10	2.35	0.34	B
72C-10	54.7	0.10	1.50	0.41	B
72D-06	93.0	0.05	1.90	0.36	B

[1]The first two digits indicate year of experiment; the letter following the year indicates the planned separate reports (X, Y, A, B, C, and D). The last two digits indicate the tank used for the experiment (6- or 10-foot tank).

[2]Determined for given wave period and constant water depth of 2.33 feet, so that generated wave energy flux computed from linear theory had a constant value of 5.8 foot-pounds per second per foot.

[3]The cumulative time at the end of each run for the two surveying sequences is defined in Table 2.

NOTE.--The same sediment was used in all 10 experiments; however, the initial average d_{50} (by dry sieve analysis) of quartz sand was 0.23 millimeter in 1971 and 0.22 millimeter in 1972.

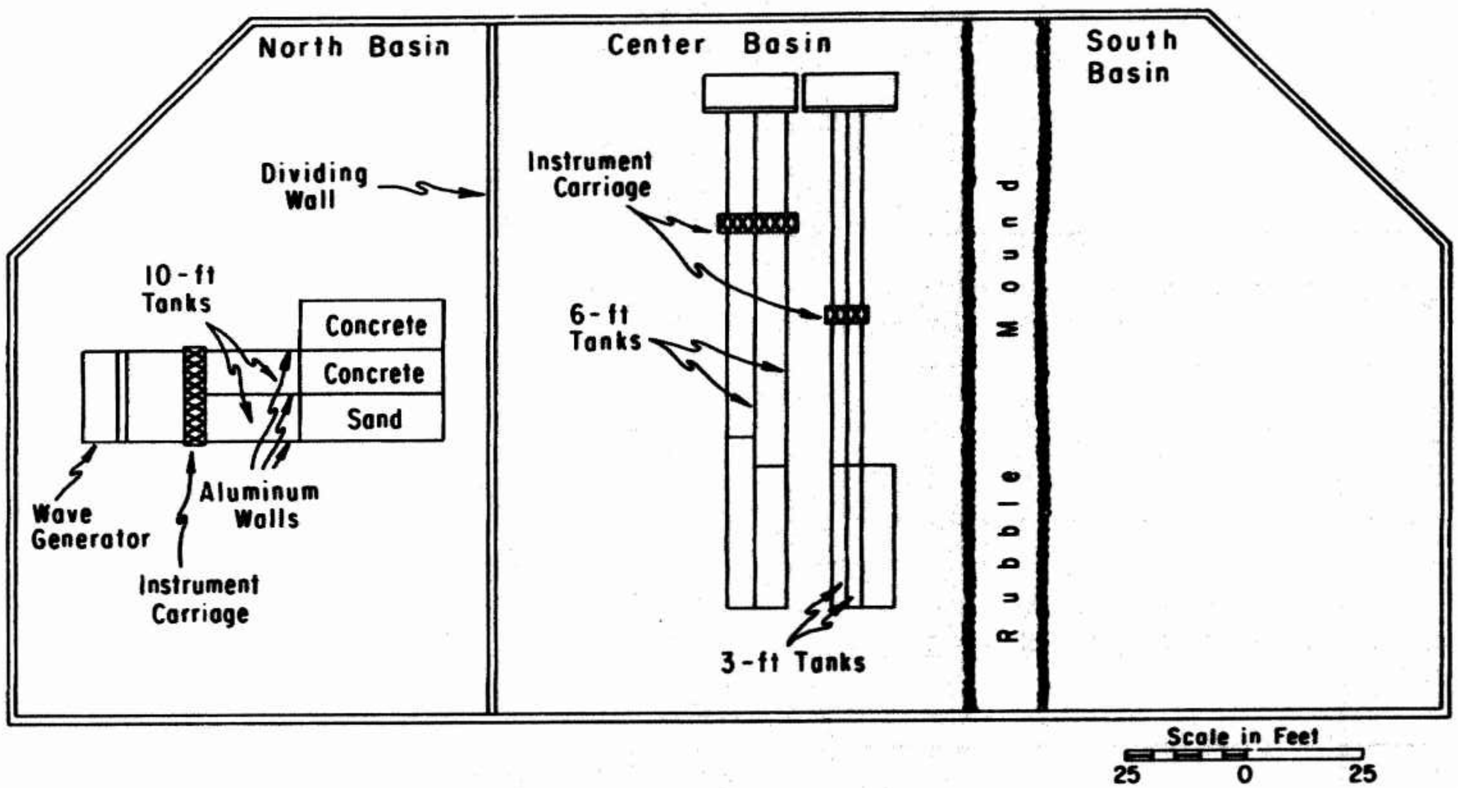

Figure 1. Plan view of the Shore Processes Test Basin (SPTB).

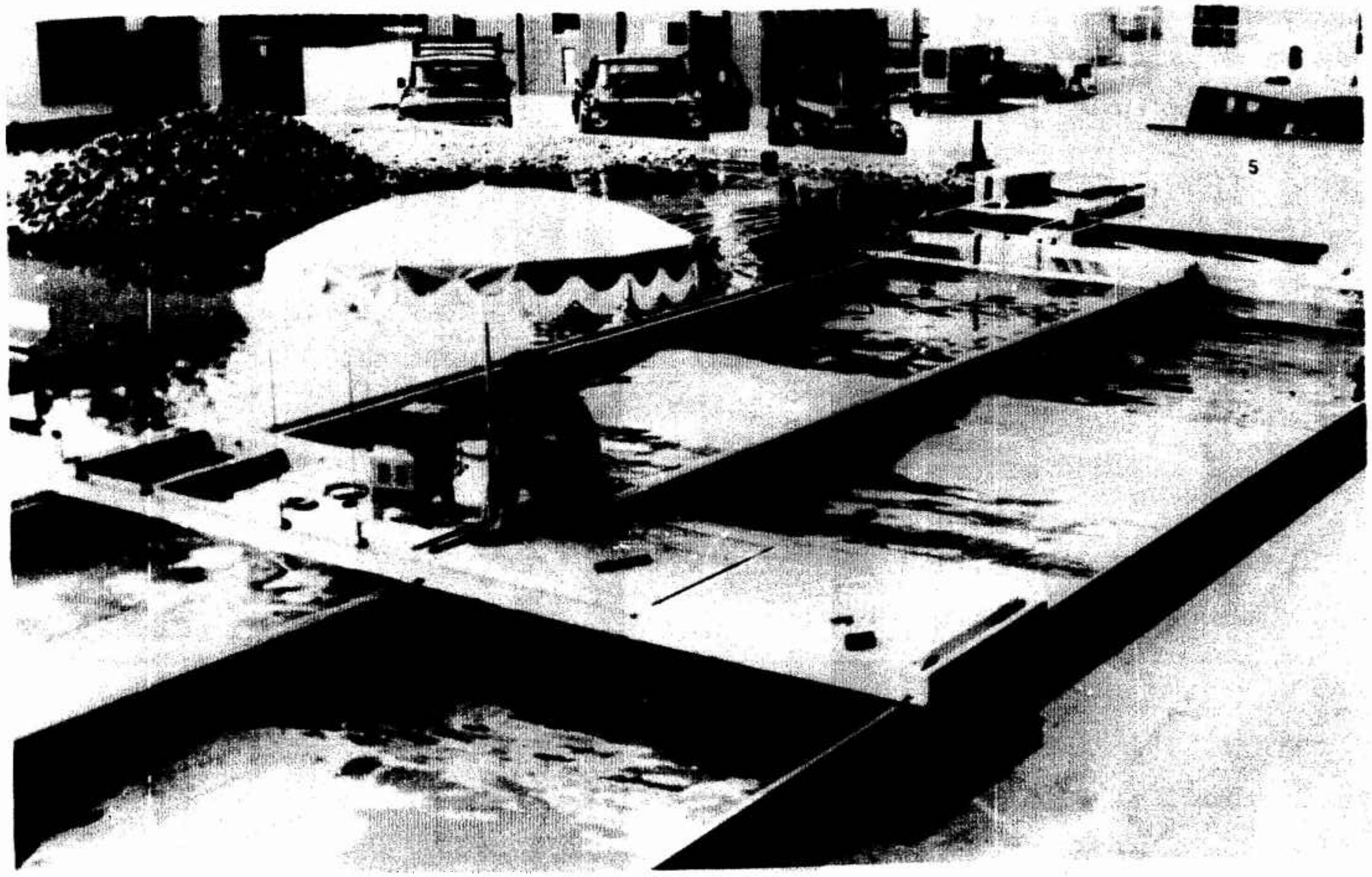

Figure 2. North section of Shore Processes Test Basin.

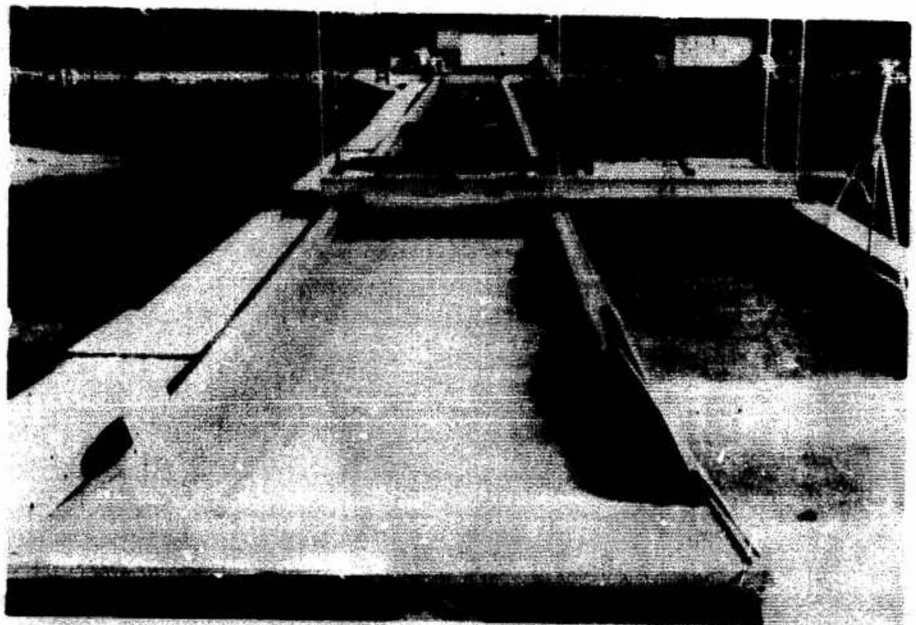

Figure 3. Seaward-looking view of 6-foot-wide wave tanks.

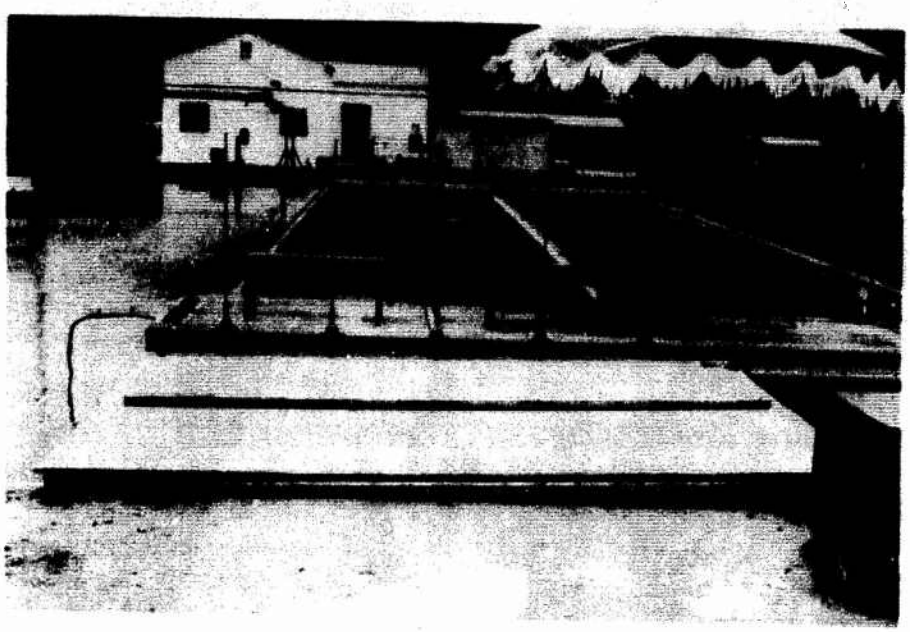

Figure 4. Seaward-looking view of 10-foot-wide wave tanks, with protective covers over subaerial beach.

Table 2. LEBS profile surveying sequences.

Survey No.	Sequence A (hr:min)	End of experiment (No.)	Sequence B (hr:min)	End of experiment (No.)
1	0:00		0:00	
2	0:10		0:10	
3	0:25		0:40	
4	0:40		1:30	
5	1:00		3:00	
6	1:30		5	
7	2:00		10	
8	3		15	
9	4		20	
10	5		25	
11	6		30	
12	7		35	
13	8		40	
14	9		45	
15	10		50	
16	12		55	
17	14		60	
18	16		65	
19	18		70	
20	20		75	
21	22		80	72A-10
22	24		85	
23	26		90	
24	28		95	
25	30		100	
26	32		105	
27	34		110	
28	36		115	
29	38		120	
30	40		125	
31	42		130	
32	44		135	72A-06
33	46		140	72C-10
34	48		145	
35	50		150	72B-06 72B-10
36	52		155	
37	54		160	
38	56		165	
39	58		170	
40	60		175	
41	62		180	72D-06
---[1]	---[2]			
---[1]	---[2]			
---[1]	---[2]			
60	100			
61	105			
---[1]	---[3]			
---[1]	---[3]			
---[1]	---[3]			
75	175	70X-06		
---[1]	---[3]			
---[1]	---[3]			
---[1]	---[3]			
82	210	70X-10		
---[1]	---[3]			
---[1]	---[3]			
---[1]	---[3]			
107	335	71Y-10		
---[1]	---[3]			
---[1]	---[3]			
---[1]	---[3]			
115	375	71Y-06		

[1]Increments of 1.
[2]Increments of 2.
[3]Increments of 5.

successive runs for the two different run sequences, and the duration of each experiment. During each run, test condition control data, including stillwater surface elevation and wave period, and independent variable data, including wave reflection measurements, breaker and runup observations, and current data (in 1972) were collected. Profile surveys were made after each run. Water temperature was monitored twice daily (morning and evening). Less frequently, with the wave tanks drained, ripple formations were photographed, surface sand samples were collected, and additional smaller grid surveys were made. The basin was drained slowly to minimize erosion damage to the ripples, which could be caused by ground water seepage or impoundment by ripples and bars.

3. Records.

Since various types of data were collected, an organized procedure for recordkeeping was developed. The primary record was the laboratory notebook in which a daily log of test activity was maintained. To ensure that a complete, detailed account of all test events was obtained for later reduction and analysis, other data collection forms were necessary. An example and a brief description of the significant types of data collection forms are given in Appendix A. Standardization in data collection was achieved by either using regulation forms or designing new forms for specific types of data.

4. Profile Construction.

The sand beach was graded using the same procedure in each experiment to minimize the possible effects of unequal compaction. The sand, when shoveled into the tanks, was loosely packed and higher elevations than desired were established for the initial grading. The basin was completely filled and then drained, allowing the sand to compact before the slope was regraded to the exact elevations desired. The basin was then filled to the standard depth and after 24 hours the initial survey was made. The intersection of the SWL with the initial sand slope at the center wall was established as the origin of the coordinate system (defined in Fig. 5).

5. Profile Protection.

Every evening and during inclement weather, plywood covers were placed over the subaerial part of the profile to prevent damage from wind or rain (Fig. 4). A plastic sheet was placed over the plywood covers to prevent water from dripping through the gaps between the covers. This practice also allowed a run to be completed if it rained. When runs were not in progress, a plywood sheet was lowered into the water (without disturbing the profile) at the seaward end of the covers to prevent wind-generated waves from reaching the beach. Copper sulfate was added to the water weekly to retard the growth of algae, which can cement the sand bottom and retard sediment motion. Leaves frequently fell into the test area, and daily cleaning of the subaerial beach and water surface was necessary.

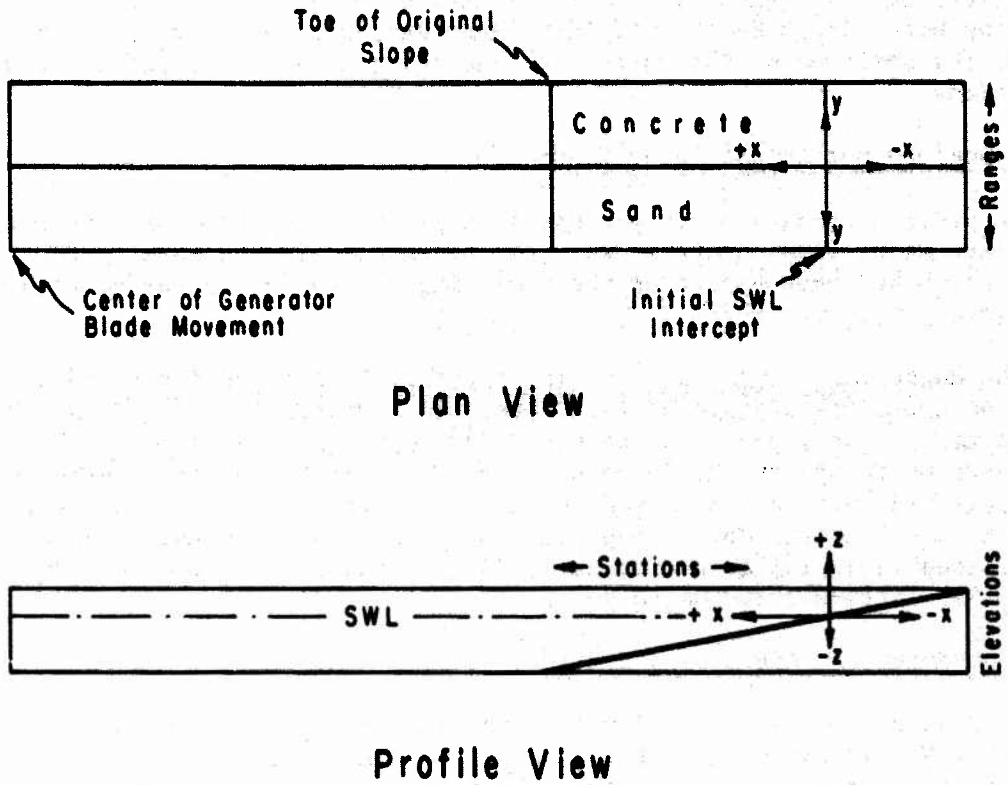

Figure 5. Definition sketch of coordinate system.

III. WATER LEVEL CONTROL

1. Necessity.

The SPTB plumbing system is shown in Figure 6. A constant water depth was maintained throughout a test to eliminate, or minimize, the effect of changing water depth on the (a) instrument carriage-to-water level distance, (b) position of the shoreline, and (c) generated and reflected wave conditions.

2. Procedure for Establishing Control.

In order that data be comparable in a given test area from 1 year to the next, water level criteria were established in 1970 according to criteria which had been used from the beginning of service of the particular test area within the SPTB.

The north basin was filled to the approximate desired depth and then adjusted until the average of the depths along ranges 1, 3, 5, 7, and 9 at the toe of the concrete slope was 2.340 feet (the reference depth in earlier experiments in the 10-foot tanks). A 4-inch-long (10 centimeters) notch was made with a hammer and chisel at the east end of the concrete slope at the SWL intercept. The reference depth in the 6-foot tank was established in a similar manner at 2.330 feet and a black line was drawn at the SWL intercept on the concrete slope.

3. Procedure for Maintaining Control.

To monitor the water level while the wave generators were running, a point gage was rigidly mounted about 1 foot inside the tank wall adjacent to the hydrant (Fig. 7). The rubble absorber in this area provided good to excellent damping depending on the wave period used. With the SWL intersecting the concrete slope at the previously marked reference, the point gage was carefully adjusted to read some easily remembered value which was used as a constant for the test season. A 2-inch feeder line continuously added water to the basin during testing to offset the losses from leakage and evaporation (Fig. 7).

The water level was checked and recorded three times during each run: the start, midway, and near the end. However, readings were made more frequently when conditions warranted.

4. Problems Encountered.

Three conditions which commonly caused difficulty in maintaining the desired water level during test intervals were (a) improperly adjusted feeder line valve, (b) change in water-main pressure when filling the large wave tank, and (c) rain.

The practical tolerance in water level was ±0.002 foot (±0.6 millimeter). Factors affecting the establishment of this tolerance were (a) basin

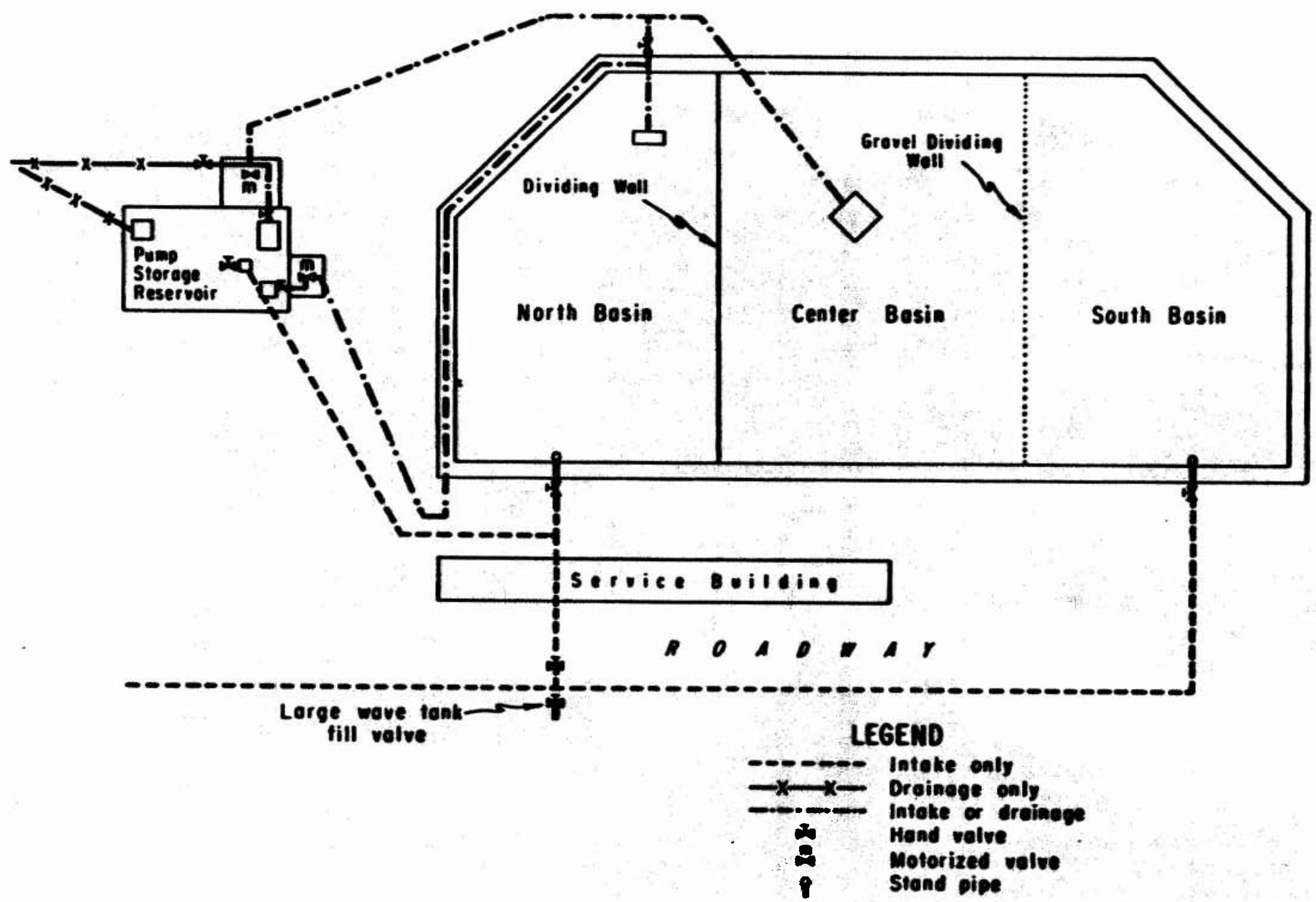

Figure 6. Valve and pipe system of the Shore Processes Test Basin.

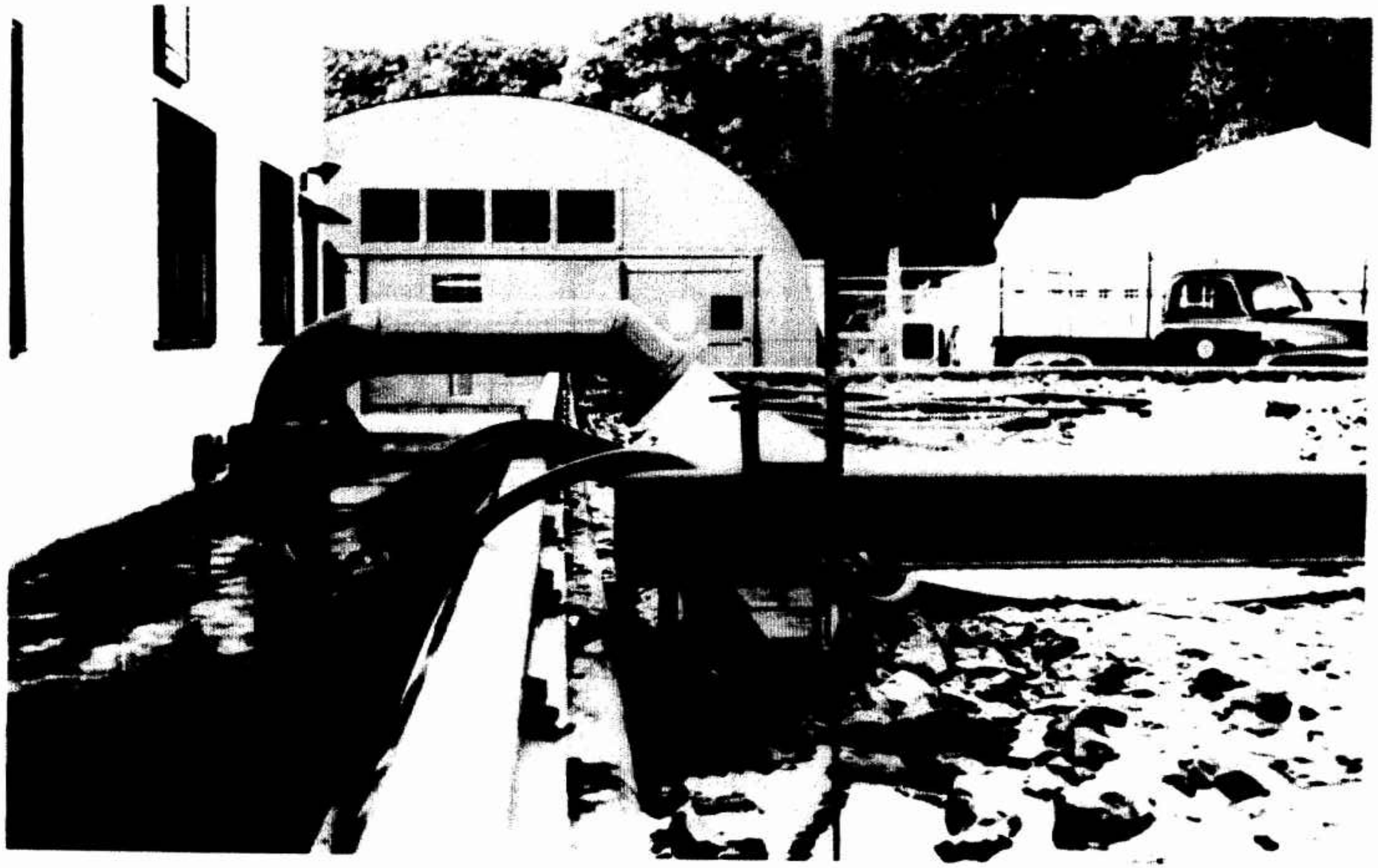

Figure 7. Water level gage and hydrant.

oscillations due to wind and waves, (b) visual error in taking gage readings, and (c) variations in readings due to different observers. Wave-generated oscillations were problems only with the long wave (3.75-second period). Basin oscillations due to wind caused a problem perhaps once in 10 days. The wind effect was compensated by adjusting the water level until the average of the maximum and minimum gage readings equaled the desired reading.

5. Water Depth.

Although the water level at the gage was maintained to very strict tolerances, the water depth is not considered that accurate because the bottom elevation varied as much as 0.1 foot (3 centimeters) within the 6-foot tank and 0.05 foot (1.5 centimeters) within the 10-foot tank. A contour map of a part of the 10-foot tank bottom derived from data collected in December 1972 is shown in Figure 8. A similar drawing of the 6-foot tank bottom is shown in Figure 9.

IV. WAVE GENERATOR OPERATION

1. Experimental Setup.

Each test area was equipped with 1 of the 10 SPTB portable wave generators (Fig. 10). The generator was placed perpendicular to the three walls and a sufficient distance from the ends of the walls to allow maximum bulkhead travel without striking the walls. A plate was attached perpendicular to the generator bulkhead in a position to slide against the center wall, thus completely separating the two tanks regardless of bulkhead position. In the 6-foot tanks, plates were also attached perpendicular to the bulkhead just inside the outside walls (Fig. 10), thus making a closed tank wall regardless of the bulkhead position. The outside walls of the 10-foot tank extended to the frame of the wave generator. There was no gap between the end of the tank wall and the generator frame, but a 0.15-foot (4.6 centimeters) gap was between the end of the generator bulkhead and the generator frame (Fig. 11). This is important in the analysis of results from experiment 72B-10.

2. System Components.

The generators were operated from a control room on the second floor of a service building overlooking the SPTB. Remote control was achieved by a system of electromechanical connections. The basic components of this system, for each generator, consisted of:

(a) A 20- by 3.5-foot (6.10 by 1.07 meters) vertical bulkhead.

(b) A shaft and crank mechanism which imparted approximate sinusoidal motion to the bulkhead.

(c) A four-speed transmission connected to the crankshaft by chain and sprockets. Change of gear ratios has rarely been

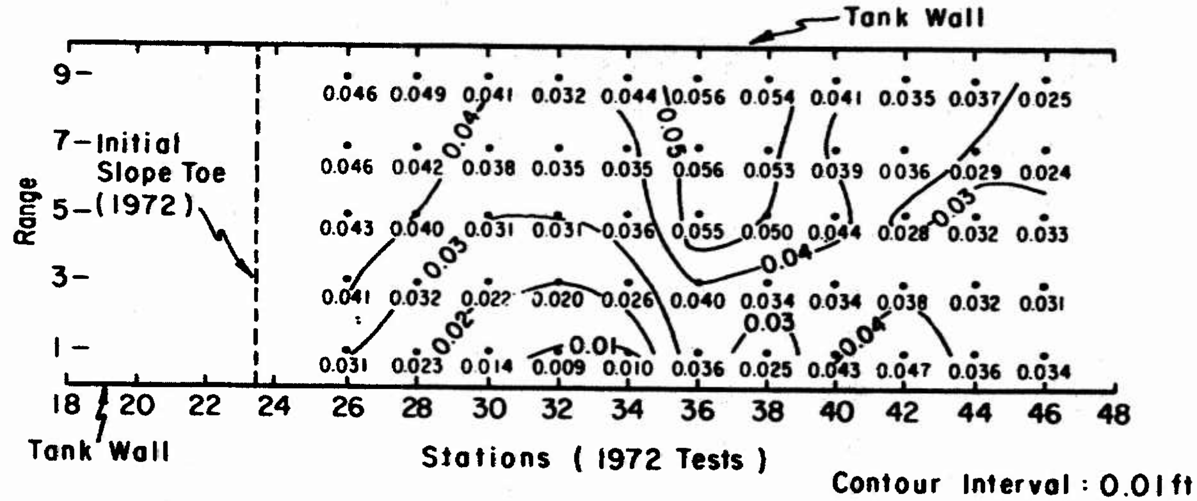

Figure 8. Contour map of concrete bottom on sand side of 10-foot tank.

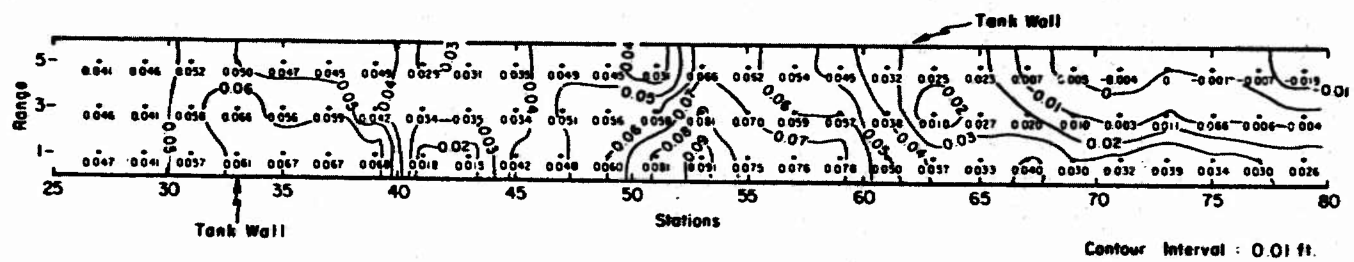

Figure 9. Contour map of concrete bottom on sand side of 6-foot tank.

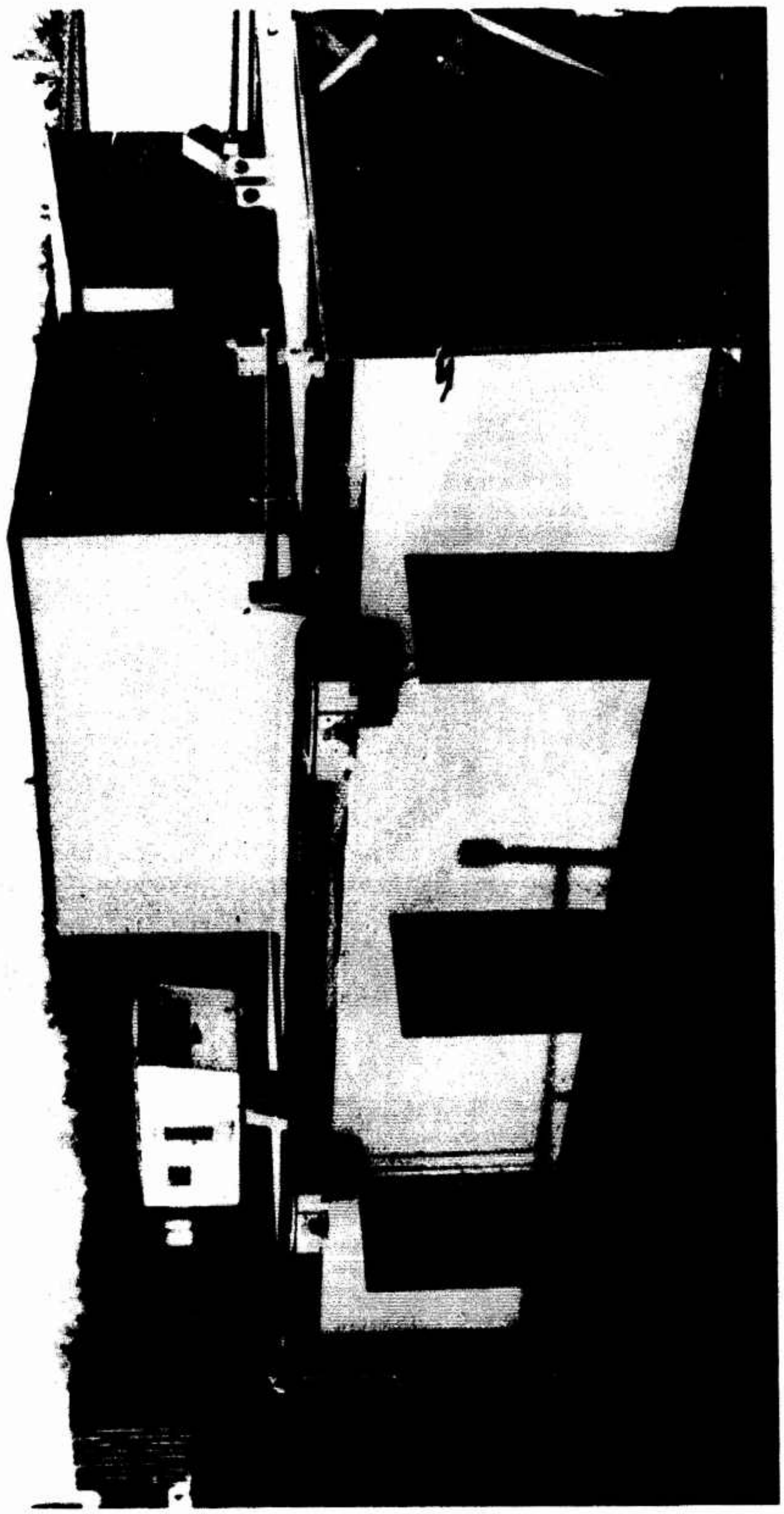

Figure 10. Portable wave generator with wall closing plates (SPTB).

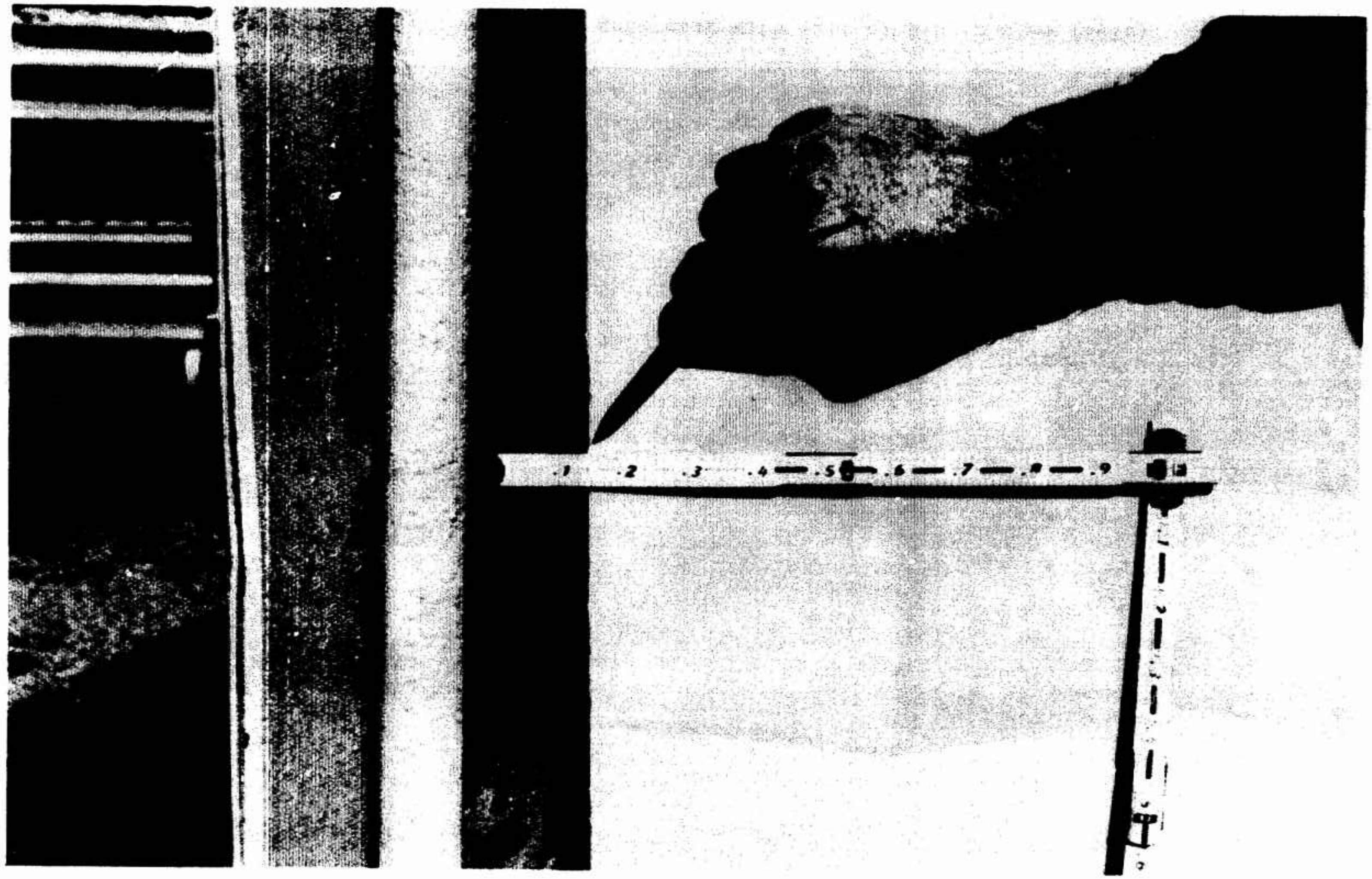

Figure 11. Gap between the generator frame and end of the generator blade.

necessary; however, change in output speed, or wave period, was accomplished by other means (see components f and g).

(d) A three-shaft input differential gearbox coupled to the transmission by chain and sprocket drive.

(e) A constant-speed, alternating current (a.c.) main drive motor. This 7.5-horsepower motor was connected to one input shaft on the differential gearbox by belts and pulleys and supplied the output power for the differential.

(f) Two smaller variable-speed direct current (d.c.) motors, with one connected to each of the two remaining input shafts of the differential by flexible couplers. The rotation speed of the single output shaft of the differential was determined by the difference in speed of the two d.c. motors. The single output of the differential drove the remaining power train to the bulkhead. Output speed, or period, of the wave generator was therefore set by regulating the speed ratio of the d.c. motors.

(g) Electrical and mechanical apparatus to control the speed of the d.c. motors. Functional parts consisted of a d.c. tachometer and slave resolver (a.c. phase-shifting mechanism) located on the wave generator and a master resolver, an a.c. to d.c. rectifier-amplifier, and a variable-speed drive connected to the master resolver located in the control room. By adjusting the varidrive speed, the master resolver speed was controlled, and, through the slave resolver and amplifier, the speed ratio of the d.c. motors was set.

The interaction of the generator and control system components, and operating procedures are given in Appendix B.

3. Wave Period Control.

In addition to setting an initially correct wave period for a given experiment, it was necessary to monitor the period throughout each individual run. The varidrive stability was affected by temperature rise of the unit during a run, but this effect was minimized by running the varidrive for at least 20 minutes before starting the run. If not allowed to warm up, the drive was adjusted to the desired period within the first 5 minutes of the run and was monitored more closely than the normal schedule. For the normal schedule, the period was checked and recorded a minimum of five times during each run, with three checks during the first hour of 5-hour runs and four checks during the first hour of 2-hour runs. After 1 hour the drive stability was found to be within the human error of observation. By repeatability tests and the comparison of checks by experienced and inexperienced personnel, conscientious observations rarely varied more than 0.2 second per 20 revolutions of the generator shaft. The procedure to check the period was to count 20 revolutions of the generator crank arms (or 60 revolutions of the speed reference shaft; see App. B) while

timing with an electric stopclock graduated in hundreds of a second. An error of 0.2 second per 20 revolutions resulted in an error of ±0.01 second in the wave period.

4. Wave Period.

The original plan for the 1970 tests called for a wave period of 1.88 seconds. However, early in experiment 70X-10 it became difficult to maintain this period due to wear of the varidrive. After 14 testing hours, the period was changed to 1.90 seconds. Wave periods of 3.75, 2.35, 1.50, and 1.90 seconds were selected for the 1972 experiments to provide a wide range of wave energy densities. These four wave periods had all been used during longshore transport tests in the early 1960's by Fairchild (1970a).

5. Problems Encountered in Operation.

The complexity of the wave generators and their control mechanisms virtually assured some operational difficulties; i.e., the generator would not "lock in" with the control mechanism, or the generator would run with an irregular angular velocity. The lock-in problem generally occurred on damp, rainy days. Balancing the control adjustment did not always solve the problem, especially when humidity or rain resulted in voltage leakage in the control circuits. Depending on the degree of voltage leakage, the solution ranged from repeated attempts at locking in the generator to waiting for the equipment to dry out, perhaps until the following day. The procedure for locking in the generator is discussed in Appendix B.

The corrective procedure for irregular rotation was the adjustment of the balance control in a clockwise direction until operation appeared uniform. The appearance of uniform rotation was not proof that the rotation was uniform. Due to the complexity and many steps of power transfer in these generators, the presence of uniform angular rotation with any degree of certainty has always been in doubt. Further, it was largely a matter of test personnel vigilance whether or not the optimum rotation was maintained. A further risk existed that, should the irregular rotation not be corrected, the irregularity would increase until the servomechanism would lose control completely. In this event, the generator would "run free" at whatever speed, or period, the power of the main drive mechanism would allow. For the 2.35-inch (5.97 centimeters) eccentric setting (1970 and 1971), the period was about 1.25 seconds. Any prolonged interval, especially one of unknown duration of these "run away" waves on the beach, would have been disastrous to the experiment. However, all occurrences were observed and corrected within 1 minute except an occurrence of 5- to 10-minute duration in experiment 71Y-06.

Initial irregular bulkhead motion had an undesirable effect on the first waves of each test run. Even with optimum control adjustment, the irregular motion was quite pronounced until the generator stabilized. Examination of the initial wave record from each test of 1970 and visual observation indicated that at least the first five waves arriving at the

slope toe were affected by this irregular rotation resulting from the acceleration and load demand placed on the generator at startup.

6. Generator Stroke.

The generator stroke of 4.70 inches (11.94 centimeters) for the 1970 and 1971 experiments was chosen because several earlier experiments had used that setting. This travel was obtained by adjusting the crankshaft arm on each end of the generator to an eccentricity of 2.35 inches. The maximum possible offset was 8.00 inches (20.32 centimeters), by means of a threaded bar and locking assembly. For these generators, the eccentricity was one-half the stroke. A photo of the eccentric assembly on one of the generators is shown in Figure 12.

The generated wave height (the height produced by the generator motion before reflection) for the 1.90-second wave was determined before 1970 to be 0.36 foot, but no documentation exists to prove how or when that value was determined. The nominal incident wave height (generated height plus re-reflected wave height) of 0.36 foot was determined by averaging all the incident wave heights from the fixed-bed tanks from experiments 70X-06 and 70X-10 (Table 3).

In 1972, the eccentricity settings were determined by a trial-and-error procedure to generate a wave height for the selected wave period which resulted in a wave with the same energy flux as the 1970-71 wave.

V. WAVE HEIGHT DATA

1. Data Collection.

a. Wave Gages. Wave height in each test was measured with identical instrumentation which consisted of a strip-chart recorder and FWK Model-1 CERC laboratory wave gages, with the necessary parallel wire probes, cables, and connectors. Each set provided two channels of recording. The operation and calibration of this apparatus were described by Stafford (1972).

Many of the delays and problems of instrumentation were caused by the necessary daily assembly and disassembly of the equipment. Cables and connectors were especially subject to wear, with resultant higher failure than inplace instrumentation. However, this delay was minimized by availability of spare parts and prompt service from the CERC Instrumentation and Equipment Branch, Research Division (CERRE-IN).

b. Calibration. Proper gage calibration is essential in obtaining accurate wave height data. About 20 to 30 minutes was required for the instruments to reach an acceptable level of electrical stability between power application and calibration. The calibration procedure by Stafford (1972) was followed. Electrical interference, wind, and nonlinearity were frequent problems in the calibration of the wave gages. The electrical interference was part of the assembly problem and was solved by a thorough

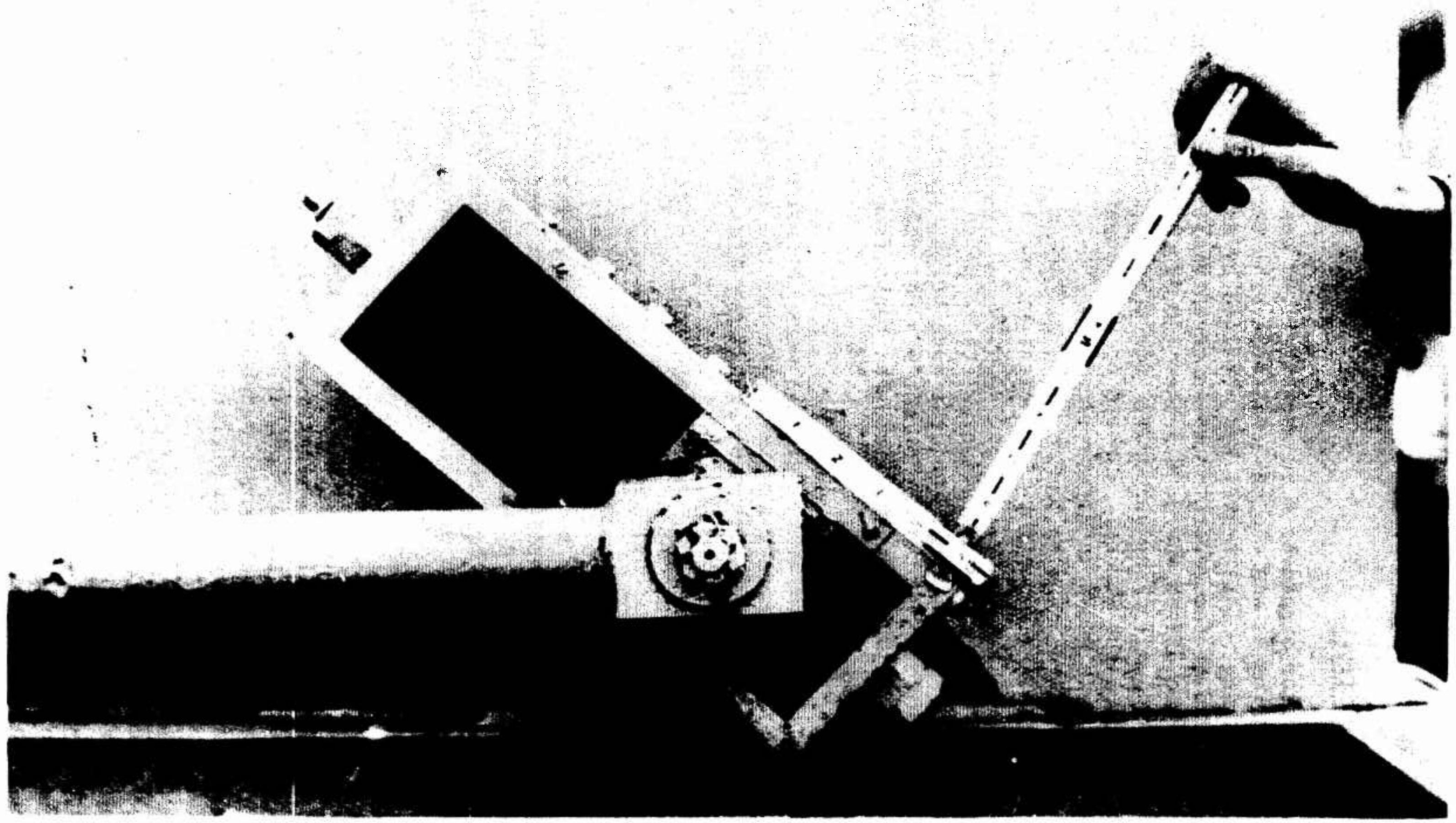

Figure 12. Eccentric setting on portable generator.

Table 3. Incident wave height for fixed-bed experiments 70X-06 and 70X-10.

Time (hr)	70X-06	70X-10
0.5	0.37	
0.8		0.38
0.8		0.38
1.8	0.36	0.37
1.8		0.37
4.3	0.37	
4.3	0.37	0.37
9.3		0.35
9.3	0.36	
19		0.36
19	0.37	0.36
27	0.37	
27	0.37	
29		0.35
29		0.35
39	0.39	0.35
39	0.37	0.35
49	0.37	
49	0.37	
51		0.36
51		0.36
53	0.37	
53	0.37	
59	0.37	0.35
59	0.37	0.35
65		0.35
65		0.35
69	0.37	
69	0.37	
77		0.35
77		0.35
79	0.37	
79	0.37	
89	0.36	0.35
89	0.36	0.35
99	0.37	0.36
99	0.36	0.35
124	0.37	0.36
124	0.36	0.36
149		0.36
149		0.35
169		0.36
169		0.35
174	0.37	0.36
174		0.36

check for faulty electrical connections and filtering. Wind interfered with the calibration process by generating ripples and occasionally basin oscillations. The only solution was to wait for calm. Nonlinearity was usually reducible to ±0.5 percent of full scale by manipulation of the parallel wire probes as described by Stafford (1972). Occasional occurrences of very heavy rains caused a short-term drift and gain problem which hindered the calibration of the gages. The rain would leave a top layer of water which had a different conductivity due to different chemical content and temperature. The different conductivities at different water depths caused unequal flow of current per unit length of probe and as the probe position changed relative to water depth during the calibration process, electronic balance and amplification changed. This was another form of nonlinearity, which would be resolved only by natural mixing of the water. As the heavy rains also caused generator operating problems, testing was delayed until the following day (see Sec. IV, 5).

c. Calibration Check. Another significant step in determining wave record accuracy was the calibration check. Within minutes after the completion of each individual run, a sufficient number of calibration marks were placed on the record to determine the amount of drift and change of gain that had occurred since the initial calibration. Drift is not an impairment to data reduction, as long as the trace remains within the chart-paper grid. In determining reflection coefficients, the change of gain can be disregarded, since

$$K_R = \frac{\Delta g H_A - \Delta g H_N}{\Delta g H_A + \Delta g H_N} = \frac{\Delta g \ (H_A - H_N)}{\Delta g \ (H_A + H_N)} = \frac{H_A - H_N}{H_A + H_N} ,$$

where

K_R - reflection coefficient

H_A = height of wave envelope antinode

H_N = height of wave envelope mode

Δg = change of gain

Stafford (1972) verified that the change of gain occurring during a run is linear to the degree that the initial calibration is linear. Therefore, for reflection coefficients the linearity of the initial calibration is the prime consideration.

The change of gain is important in analyzing absolute wave heights. Immediately after each run, the calibration was checked and the amount of gain change since the initial calibration for each channel was recorded on the wave record and in the log. The log data showed gains of from 0.5 to 4 percent above the initial calibration, with an estimated 80 percent of the measurements within this range; e.g., in 1970, only four cases of 10- to 11-percent gain were observed. Losses on the calibration checks were

rare. Although changing water temperature is the predominant cause of gain change, it appears that, in outdoor testing in the SPTB, there were other causes, including perhaps the chemicals in the water. Sufficient information is not available to determine the nature and extent of these other causes. When records are to be analyzed for wave heights, the measurements should be adjusted to account for the change in gain. Since there is no method for determining at what time between the initial calibration and the calibration check the change in gain occurred, the maximum error, as shown by the calibration check, should be assumed for all data during this time interval.

d. Recording of Wave Envelopes. All instrumentation was placed on a carriage which moved along the tank and recorded a profile of the water surface. The envelope was recorded during each run (except for the first 10-minute run) by turning on the recorder at a slow chart-paper speed while the carriage was propelled slowly along the tanks with a handcrank and cable system. One envelope was recorded from station +15 to the generator, the second envelope on the return. The desired carriage speed was 10 feet per minute. However, due to mechanical problems early in each testing season and since the carriage was propelled by hand, this velocity was only approximate. To assist in determining the speed of the carriage, a magnetic relay mechanism was installed in each test area so that the event marker on the strip-chart recorder would mark the position of the carriage at 5-foot (1.52 meters) intervals. During the recording of each envelope, the appropriate station identification was written by the instrument operator on the chart paper adjacent to these pen marks.

2. Data Reduction.

A manual method and an automated method were used in the reduction of wave reflection data. In 1970, the manual method was used to analyze all the wave records and the automated method for 20 percent of those wave records. In 1971, each method was used to analyze all data. In 1972, 61 percent of the data were analyzed by the automated method, 28 percent by the manual method, and 11 percent by both methods.

a. Manual Method. Using the 5-foot event marks as an approximate scale and knowing that nodes and antinodes should be one-quarter wavelength apart, the approximate locations of nodes and antinodes were determined over the constant depth section of each tank. Wave heights were measured from the preceding trough to the crest. The high wave and the low wave along these intervals were then precisely determined by choosing the highest or lowest wave having at least three increasing or three decreasing waves immediately adjacent to the wave. Pairs of nodes and antinodes were then measured by increments (0.065 inch or 1.66 millimeters) on the chart paper, to the nearest 0.2 increment (0.013 inch or 0.33 millimeter), and a K_R determined for each pair using:

$$K_R = \frac{H_A - H_N}{H_A + H_N} = \frac{H_R}{H_I} .$$

The several K_R values along the envelope were averaged to determine the K_R for the envelope.

b. Automated Method. An automated method of determining wave reflection coefficients was developed as part of this study. At times it is difficult to identify the location of the node and antinode on a wave envelope in intermediate or shallow water, particularly for conditions of low wave reflection. The automated method eliminates the subjective aspect of determining the location of nodes and antinodes. Because the automated method uses all wave heights of the envelopes and not just the extreme values, it is statistically more meaningful.

(1) Description of the Method. Figure 13 shows one wavelength of an idealized wave envelope for a sinusoidal wave and partial reflection. The reflection coefficient is the ratio of the reflected wave height to the incident wave height, and in both methods the incident wave height is an average height of measured waves. In the manual method the incident wave height is the average of the two extremes, the nodes and antinodes of the envelope; i.e.,

$$[H_I]_{MANUAL} = \frac{H_1 + H_5}{2} \quad .$$

In the automated method the incident wave height is the average of all waves; i.e.,

$$[H_I]_{AUTOMATED} = \frac{H_1 + H_2 + \ . \ . \ . + H_8}{2} \quad .$$

The carriage must be moved at a constant speed to gather unbiased data.

In the manual method the reflected wave height is the difference of the two extreme heights divided by 2; i.e.,

$$[H_R]_{MANUAL} = \frac{H_1 - H_5}{2} \quad .$$

An exact procedure arrives at basically the same number in the automated method. The difference between the average wave height and the individual wave height is plotted versus distance along the envelope. In an ideal case where the wave shape is sinusoidal and the carriage is moved at a constant speed, this curve would be a sine curve, with a maximum value at the antinode of the envelope and a minimum at the node of the envelope. The amplitude of the sine wave is the height of the reflected wave:

$$[H_R]_{AUTOMATED} = H_1 - H_{AVG} = H_{AVG} - H_5 = \frac{H_1 - H_5}{2} \quad .$$

Ideally, the two methods would produce the same value.

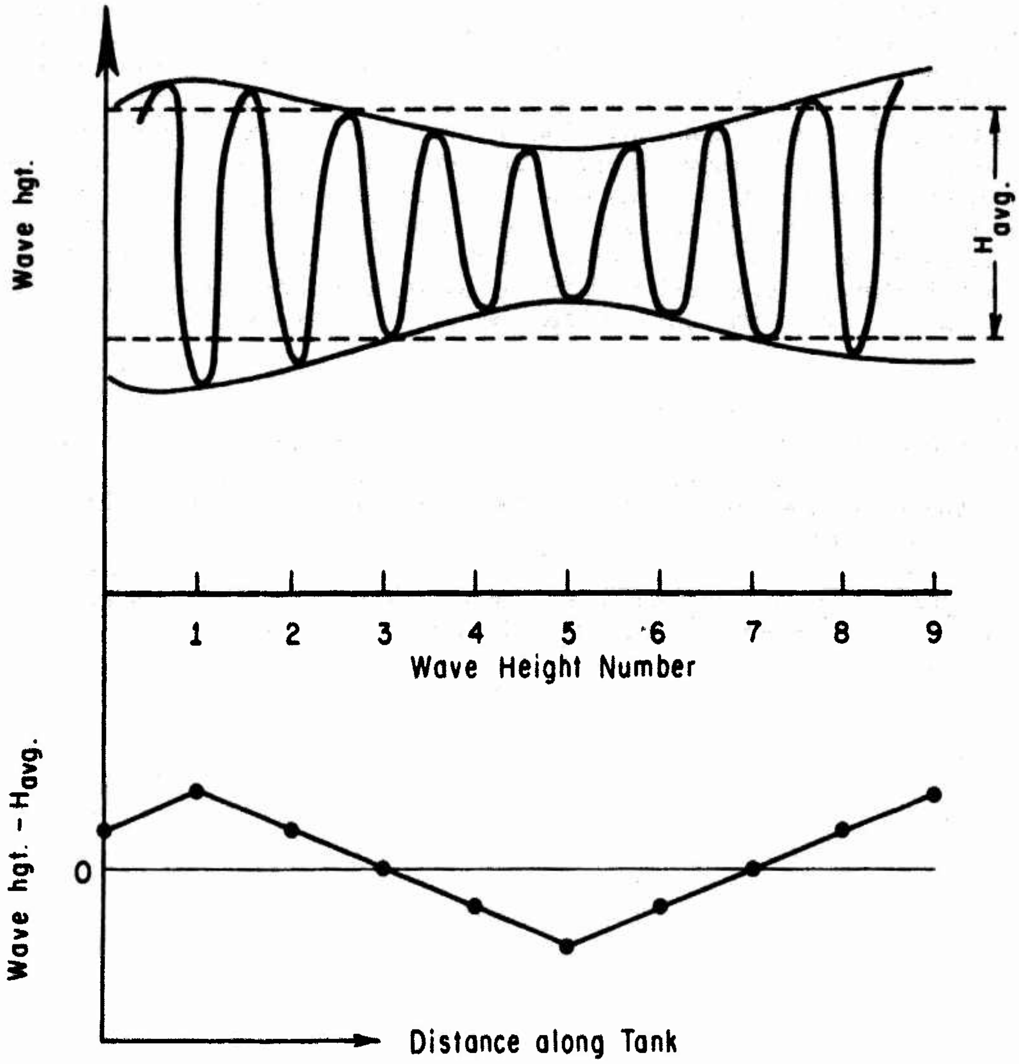

Figure 13. Idealized wave envelope.

(2) Description of the Programs. Two programs were used to process the wave data. These programs and other programs discussed later are on file in the Automatic Data Processing Office (CERDP), CERC. The first program, WVHTCN, edits the digitized wave crest and trough elevation data and reduces any selected part of the data set. The program determines the average wave height for the envelope and subtracts this average from each individual wave to obtain the individual wave height deviation from the mean. The running mean (averaged over an envelope wavelength) is calculated at each point and subtracted from the individual wave height deviation from the mean to obtain the individual wave height deviation from the local mean. The local mean is then plotted superimposed on a plot of the local mean versus distance. The wave height deviation from the local mean height versus distance is also written on tape for input to the second program, WVHTC2.

WVHTC2 computes the best fit sine curve for the selected part of the wave height deviation from the local mean curve. The values for the amplitude of the sine curve, the standing wavelength, the phase angle at the origin of the plot, and H_{AVG} (called Y_{AVG}) are written on the plot. The steps in production are given in Appendix C.

c. Comparison of the Two Methods. Results from the two methods of data reduction are compared in Figures 14 to 17. Figures 14 and 15 (K_R versus time for experiments 70X-06 and 70X-10) indicate that the time variation in reflection is fairly well duplicated; Figures 16 and 17 (plots of K_R for manual method versus automated method for the same two experiments) show that the manual method gave higher values. An assumption in using the wave envelope method for determining reflection coefficients is that the heights of the reflected waves do not change significantly during the several minutes required to record the wave envelope.

VI. SURVEY DATA

1. Data Collection.

Profiles were surveyed using the coordinate system (Fig. 5). The stations and corresponding elevations were recorded on sets of scanning forms for each range, survey number, and tank (see App. A).

a. Types of Surveys. Two surveys were made: regular and special (more detailed) surveys. Regular surveys were taken after each run according to the schedules in Table 2; special surveys were taken less frequently.

(1) Regular Surveys. These surveys were taken along profiles at ranges 2 feet (0.61 meter) apart--ranges 1, 3, and 5 in the 6-foot tank and ranges 1, 3, 5, 7, and 9 in the 10-foot tank. Elevations were measured at 0.5-foot (0.15 meter) intervals from the back of the tank to station +10, at 1-foot (0.30 meter) intervals from station +10 to +23, and 0.5-foot intervals from station +23 to the toe of the beach. An exception was experiment 72D-06, where the section of 1-foot intervals was between station +20 and +46.

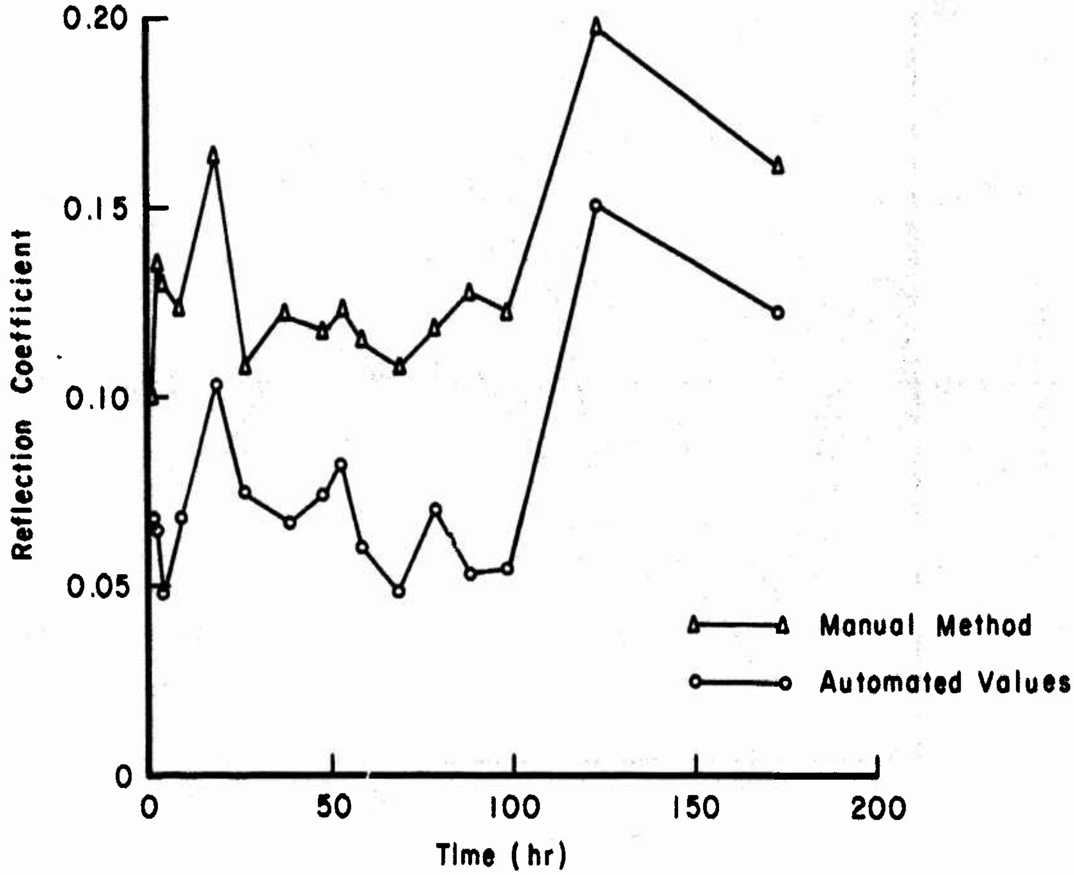

Figure 14. Lower K_R values and similar K_R trend from automated method in experiment 70X-06.

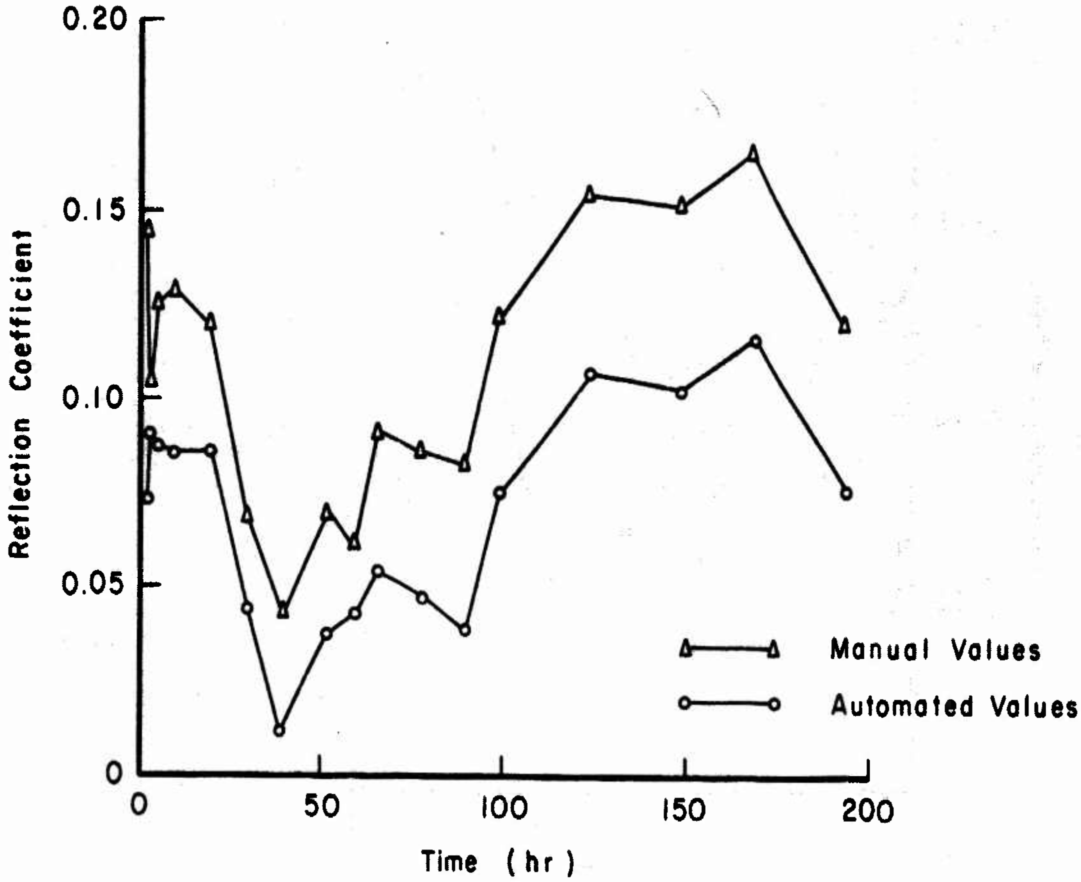

Figure 15. Lower K_R values and similar K_R trend from automated method in experiment 70X-10.

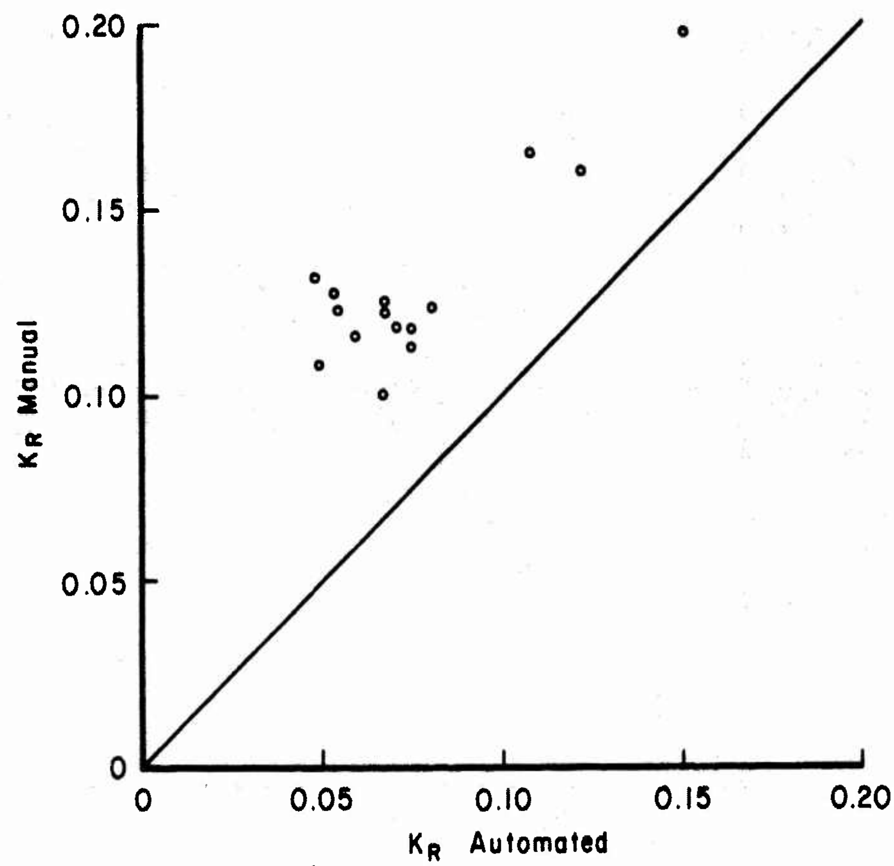

Figure 16. Correlation of manual and automated methods for determining K_R (experiment 70X-06).

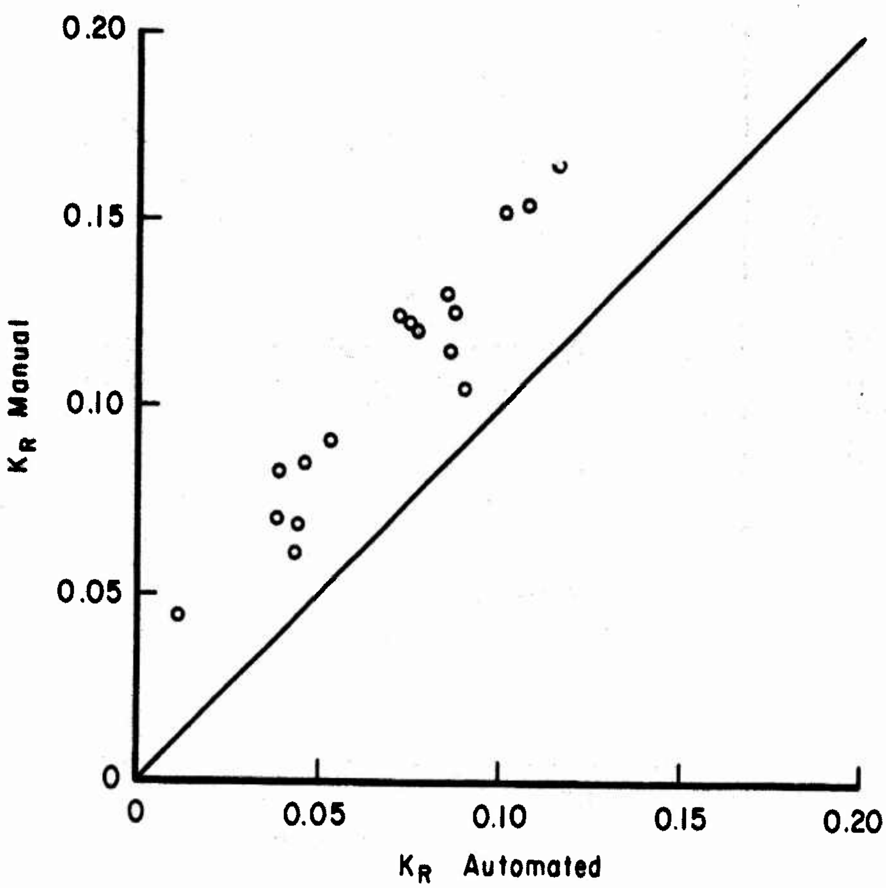

Figure 17. Correlation of manual and automated methods for determining K_R (experiment 70X-10).

(2) Special Surveys. These surveys were taken along profiles at ranges 0.5 foot apart. The ranges in the plots and tables are numbered from 05 to 60 in the 6-foot tank and 05 to 99 in the 10-foot tank. Elevations were determined at stations 0.5 foot apart; however, some of the surveys did not cover the full length of the profile.

b. Elevation Measurements. Elevations were measured using 3-foot-long (0.91 meter) gages mounted on the instrument carriage (Fig. 3). The point on the gage was replaced with a 1-inch-diameter (2.54 centimeters) gimbaled foot. The pivoting ability of this foot allowed it to attain the slope of the local sand surface and the large diameter prevented the foot from penetrating the profile surface, except in rare circumstances where the readings were obviously wrong. The gages, graduated in thousandths of a foot, were read to the nearest hundredth.

c. Survey Datum. To ensure that all elevations were measured to a fixed datum, a carriage elevation survey was taken annually, measuring the distance of the carriage above the water surface at different ranges and stations along the tank. A special gage was used to survey the distance from the carriage to the water surface. The point on a gage was modified by adding a small transistor oscillator-amplifier. When the point of the gage came in contact with the water surface, the circuit was completed, activating the oscillator and generating a tone which drove a speaker. A precise elevation of the carriage at each station could be determined with this device. The carriage elevation at station 23.5 (position of the original toe of the slope) in the center of each tank was used as the reference datum. Fluctuations in carriage elevation of more than 0.005 foot (0.15 centimeter) were corrected in the data reduction procedure. The gages were adjusted so that elevations were measured with the bottom of the tank at station 23.5 as the datum, and 2.33 feet was later subtracted from each gage reading during the automatic data reduction to convert to the SWL datum.

d. Survey Accuracy. Ripple formations on the sand surface can affect the accuracy of the local average sand surface elevation by half the ripple height. A special survey was made in 1970 to give an indication of the effect of ripples on survey accuracy. Using a point gage, distances and elevations were measured at the crest and trough of all ripples along range 9 in the 10-foot tank after 42 hours. The surveyor visually determined that the point was at the ripple crest or trough. Table 4 presents data on the frequency of occurrence of ripple heights and indicates the potential effect on survey accuracy. The data indicate that if all elevations were measured at the worst points, i.e., always at a crest or trough, 82 percent of the measurements would be within 0.02 foot (0.61 centimeter) of the actual local average elevation and 99 percent would be within 0.03 foot (0.91 centimeter).

To achieve a more realistic estimate of the effect of ripples on regular-spaced surveys, the actual error caused by ripples was determined by comparing the elevations from the regular survey with those from the special ripple survey. These data (Table 5) indicate that 64 percent of

Table 4. Frequency of occurrence of ripple heights and resulting error.

Ripple height (ft)	Occurrence (No.)	Occurrences (pct)	Error range (ft)	Cumulative occurrences (pct)
0.07	1	1		
0.06	3	4	±0.03	99
0.05	9	13		
0.04	8	12	±0.02	82
0.03	11	16		
0.02	20	29	±0.01	54
0.01	17	25		

Table 5. Actual errors due to ripples on the special ripple survey.

Error (ft)	Measurements (No.)	Pct of total	Cumulative (pct)
0.00	25	64	64
±0.01	8	20	84
±0.02	5	13	97
±0.03	1	3	100

the measurements had no error and that 97 percent of the measurements were within 0.02 foot of the actual elevations.

The position of the gages at the specified ranges was within ±0.02 foot, the maximum lateral movement of the carriage. The position of the carriage at the specified stations was never off more than 0.05 foot, the finest division on the tape.

In summary, the accuracy of the survey measurements was ±0.05 foot in the x-direction, ±0.02 foot in the y-direction, and ±0.02 foot in the z-direction (Fig. 5).

2. Data Reduction.

a. Quality Control. After initial quality control checks, the scanning sheets were interpreted using the IBM Optical Mark Page Reader, producing a card deck. The data cards were edited for scanning machine errors, missing or incorrect heading information, and bad data. The elevations were corrected for carriage elevation variations, as measured in that test year. Specific data on carriage elevation surveys and the resulting corrections used in data reduction are in subsequent reports dealing with individual experiments.

b. Data Reduction Programs. Each deck of data cards was run through the BEPROF package of programs. The BEPROF programs were developed for the CERC Beach Evaluation Program (BEP) to manipulate field survey data and were modified for use with laboratory data. The program BEPROF uses the edited and corrected deck of cards to generate a magnetic tape for use with several programs to manipulate the data. The PRFL2C program was used to display the reduced data by: (a) Plots of profiles, all surveys per range; (b) plots of profiles, all ranges per survey; (c) tables of distance to contour intercepts; and (d) punchcards with distance to contour intercepts (at depth increments of 0.1 foot for all surveys and ranges) to be used in the CONPLT program. The CONPLT program plots the x-direction movement of selected contour intercepts with time. These plots show profile changes throughout one experiment for each profile. CONPLT plots are the major means of presenting profile results in the series of LEBS data reports.

VII. BREAKER AND RUNUP DATA

1. Data Collection.

Wave breaking and runup data were collected by three methods during the 3-year experimental program: photography in 1970; photography and visual observations in 1971; and photography, visual observations, and wave gages in 1972.

a. Photography. At specified times during each run, 35-millimeter slides were taken of the wave breaking and runup. Technicians were able, with some experience, to photograph the breaking wave just as it began to spill for the spilling breaker and at the point when the face of the wave

was vertical for the plunging breaker. The slide of the runup was taken as close to the time of maximum uprush as possible. The position of the breaker was determined (from slides for 1970 and for 1971 through mid-August) by knowing the location of fixed objects visible on the slide in the immediate area of the breaker. Breaker type was also determined from the slides.

b. Visual Observations. Beginning in mid-August 1971, visual observations of the position and type of breaker and position of the wave uprush were made and recorded at the time the wave envelope was recorded. The position of the breaker could be estimated within 0.5 foot. These data were recorded in the logbooks and on the visual observation forms (see App. A for example forms).

c. Wave Gages. Attempts were made in 1972 to measure wave height in the shoaling zone (including the breaker height) at 25-hour intervals using wave gages. A specially adapted point gage for determining water surface elevations (Sec. VI) was used to measure the vertical limits of runup, also at 25-hour intervals.

2. Analysis of Breaker Data.

To analyze breaker characteristics, the type, height, and depth of breakers are required. Breaker type can be determined from the slides and from the visual observation forms. Galvin (1968) was used as a guide for determining breaker type. Breaker depth can be determined from the profile surveys knowing the breaker position. Breaker height data are available only for 1972 and then only at 25-hour intervals.

VIII. RIPPLE FORMATION DATA

At the times of the special surveys (when the wave tanks were drained), 35-millimeter slides of the ripple formations along the full length of the profile were taken. Cloth tapes and wood rules were placed on the beach forming a grid with 2- by 3-foot sections. Vertical photos of the ripple formations were taken from the top of the instrument carriage, with the cloth tapes and rules just inside the frame of each exposure. The grid assured a uniform area in each slide and the tape also provided a scale for reducing the data. In the 6-foot tank, the size of each frame was 2 feet in the x-direction and 3 feet in the y-direction; in the 10-foot tank, the size was 3 feet in the x-direction and 2 feet in the y-direction.

IX. SAND SAMPLES

1. Collection.

Sand samples were collected by scraping 10 to 50 grams from the surface of the bed when the tanks were drained after the special detailed surveys of the beach profile.

2. Size Analysis.

The 1970 and 1971 samples were analyzed by the CERC Petrology Laboratory, using the Rapid Sediment Analyzer (RSA). The U.S. Army Engineer

Division, Missouri River, laboratory, analyzed the 1972 samples using a Visual Accumulation (VA) Tube. The dry sieve method was used by project technicians to analyze 10 percent of the samples for quality control.

a. RSA Method. Analysis with the RSA consisted of allowing a split sample to settle through the tube while the pressure differential was measured with a pressure transducer, and the values digitized and punched onto IBM cards. The cards were used with the program SEDANL (on file in CERDP) to obtain a detailed listing of percentages in each 1/4 phi-size interval and other statistical parameters. Ramsey and Galvin (1977) give details on the use of this method.

b. VA Tube Method. Analysis by the VA Tube method consisted of allowing a split sample to settle through the tube while manually following the accumulation of sediment at the bottom of the tube. Colby and Christensen (1956) describe the use of this method.

c. Sieve Method. Sieve analysis consisted of pouring dried 50-gram samples into a nest of sieves (sizes 2.00, 1.00, 0.500, 0.354, 0.250, 0.177, 0.125, 0.088, and 0.062 millimeters), and then placing the samples in a Rotap machine for 15 minutes. Weight measurements were made on the Ainsworth analytical balance (graduated to 0.0001 gram).

d. Comparison. A comparison of the three techniques showed that the RSA median grain size was larger than the sieve median by 0.04 millimeter on the average, and the VA Tube median was smaller than the sieve median by 0.01 millimeter. The data also show that the average median (by sieve) of samples at the beginning of the experiments became finer, falling from 0.23 millimeter in 1971 to 0.22 millimeter in 1972. The size-distribution curves for two samples collected at 0 hours in experiments 71Y-06 and 72D-06, and the analysis of each sample by two of the three methods, are shown in Figure 18. The RSA median was 0.04 millimeter higher than the sieve median for the same sample, and the VA Tube median was 0.01 millimeter lower than the sieve method for the same sample. The sieve median in 1972 was 0.01 millimeter lower than the sieve median in 1971.

The difference between the RSA and sieve methods for this sand was 0.24 phi; Ramsey and Galvin (1977) found the difference between RSA and sieve methods to be 0.33 phi for samples from New Jersey beaches.

X. WATER TEMPERATURE AND CURRENT DATA

1. Water Temperature.

Water temperature was measured (in °Celsius) in samples collected at the bottom of the tank and at the water surface in the morning and afternoon of each test day. The water sampler could be manipulated to ensure that samples were actually taken from the bottom of the tank. These data were recorded in the logbooks, and the four values were averaged to give a daily mean temperature.

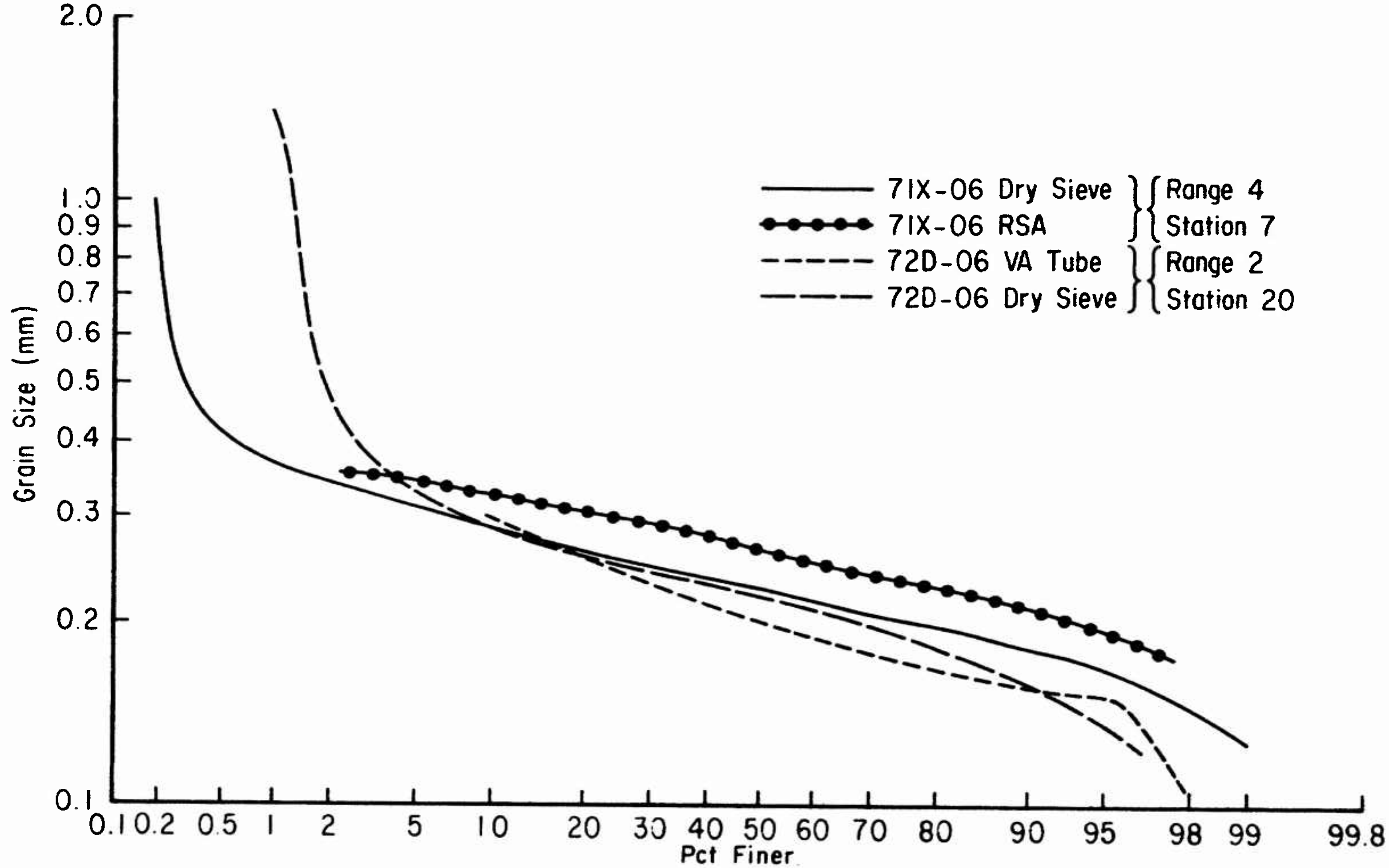

Figure 18. Comparison of results from three methods of determining sediment size distribution.

2. Current Data.

Several techniques for measuring wave-generated currents were tried in 1972 before a satisfactory technique was developed. A neutrally buoyant liquid was considered, but the liquid lacked cohesion and a color to make it distinctly visible in the water. Painted bits of Styrofoam proved too easily affected by wind. Finally, polyethylene tubing of 5/16-inch diameter (0.79 centimeter) was cut into 0.5-inch-long (1.27 centimeters) cylinders (bobs) and filled with clay just to the point of floating. The bobs were painted red and were large enough to be easily seen in the water, yet light and small enough to move with the currents. More clay was added to other bobs so that they were suspended near the bottom.

For the surface currents, the path and traveltime of each bob were recorded on a grid chart of the tank. Bottom currents were measured by recording the position and time of observation in tabular form over extended periods of time (examples in App. A).

Fluorescein dye was used for obtaining qualitative data on current patterns.

Interpretation of the current data was difficult, unless a distinct pattern was observed. In general, if a pattern of movement was observed, the reduction procedure consisted mainly of determining the velocity and changes in the circulation pattern.

XI. SUMMARY

This report is a detailed record of procedures for running a series of movable-bed coastal engineering experiments. Special attention has been given to recording those procedures which are usually transmitted informally, outside the written record, or rediscovered from hard experience. The report serves four general uses:

(a) It is a procedural manual for running coastal engineering movable-bed experiments;

(b) describes equipment that has been used since 1953 in many experimental studies published by BEB and CERC;

(c) explains procedures used in the 10 LEBS experiments (reported separately); and

(d) gives a detailed record of LEBS experimental conditions for possible future re-analysis involving presently unrecognized parameters.

The 10 LEBS experiments were conducted in 6- and 10-foot-wide outdoor wave tanks during testing seasons from April to December, to relate wave height variability to wave reflection from a changing movable-bed profile.

Water level was maintained within ±0.002 foot. The concrete bottom elevations varied as much as 0.1 foot in the 6-foot tank and 0.05 foot in the 10-foot tank. The wave period was controlled to within ±0.01 second.

The reflection coefficient was determined by both a manual and an automated method, with the automated method giving values 0.03 and 0.04 lower than the manual method for the 1.90-second wave.

Profile surveys were recorded by a point gage with a 1-inch gimbaled foot in place of the point. The survey accuracy was ±0.05 foot in the x-direction (onshore-offshore), ±0.02 foot in the y-direction (longshore), and ±0.02 foot in the z-direction (vertical). The vertical accuracy includes the effect of ripples. Data were reduced by the BEPROF package of programs at CERC.

Breaker type, position, and, in some experiments, height were determined. Ripple formations were photographed and sand samples collected when the wave tanks were drained. Sand samples were analyzed for size distribution by the RSA, the dry sieve method, and the VA Tube.

Water temperature was measured twice daily at the surface and the bottom of each tank. Current data were collected in the last six experiments by observing the paths taken by small, nearly neutrally buoyant floats.

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APPENDIX A

RECORDKEEPING

Appendix A contains examples of completed data forms used to collect each principal type of data during the LEBS testing program, 1970-72. This appendix does not include forms for data which were not uniformly or frequently collected or standard forms which were used as an intermediate step in data reduction.

1. Laboratory Logbook.

A typical handwritten entry in the laboratory logbook for a test run is shown in Figure A-1. The entry follows the standard recording sequence adopted in mid-September 1970.

2. Optical Mark Scanning Form (CERC Form 60).

This form was used to record survey data during the 3 years of the LEBS testing program. The form in Figure A-2 is an initial sheet, used to begin each profile. Successive sheets of a given profile were continuation sheets, CERC Form 83 or 43. These scanning sheets are read by an IBM Optical Mark Page Reader.

3. Wave Record Identification Labels.

Figure A-3 shows a completed handwritten sheet for wave record identification labels. In actual use the labels were separated, and one label was glued to the back side of each end of a wave record (this label was used throughout the LEBS tests). When stored in roll form, each roll had the label information readily available.

4. Wave Record Lab Coding Form (CERC Form 30).

This form (sample shown in Figure A-4) was used to log the information on the 1970 and 1971 wave records. The information was entered on the 80-column form according to the procedure in the following instructions:

a. Logging card column format for wave records in wave height variability study.

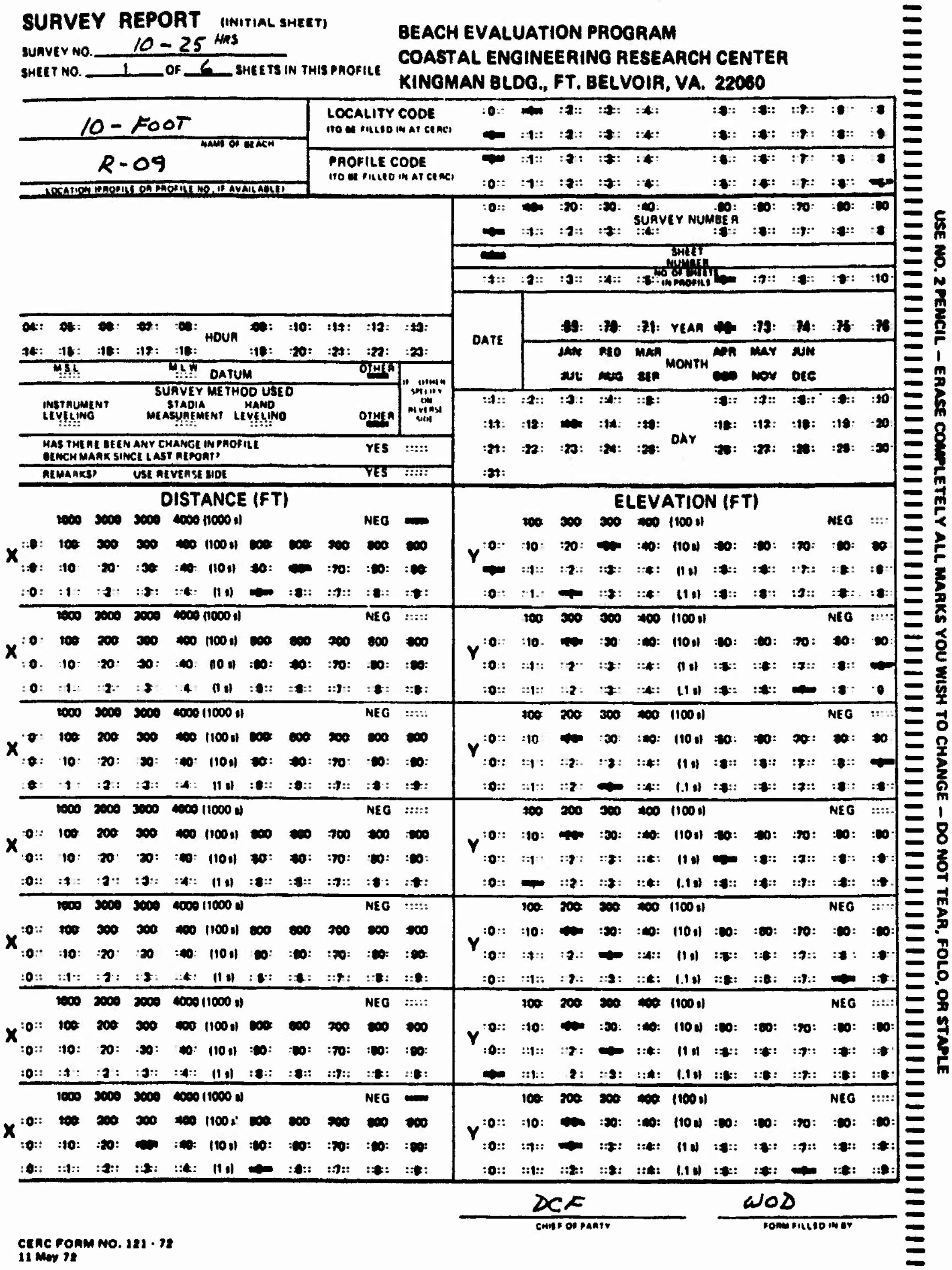
Column	Log Card
1:	card number of entry for the particular roll.
2 to 24:	identification of record in following form: column 2 to 4: roll numbers such as 016, 12A, etc. column 5 to 11: data in form 29APR68 column 13 to 16: test code in form LEB column 17 to 24: roll code in form 8N10001A

Date	Category	Time
23 Sept 71	H_2O Temperature AM	
P.D.	Top 20.1°C	7:15
	Bottom 20.1°C	
2	H_2O Level	
	Start 2.001	8:10
	Midway 2.001	10:45
	Stop 2.002	1:15
3	Run Time	
	Start 230"00"	8:15
	Stop 235"00"	1:15
4	Envelope # 85	
	Start 234" 00"	12:15
	Stop 235" 15"	12:30
5	Period Check	
	After 5" 38.00/20	8:20
	30" 38.00/20	8:45
	1" 38.00/20	9:15
	3" 38.00/20	11:15
	5" 38.00/20	1:15
6	Calibration Check	
	Sand 1% Loss	1:25
	Concrete 1%	
7	H_2O Temperature PM	
	Top 20.8°C	4:10
	Bottom 20.7°C	
8	Roll Code WHU/IC06086D	
9	Breaker Sta. -15.5 to -5.0	12:15
10	Uprush Sta. -9.4	

Survey # 89
by ~~K.S.~~ B.D.S.
Date: 23 Sept 71

Remarks.
Swift and frequent changes occurring with beach scarp scouring, fore shore and breaker appearance during first hour of test.
Only slight scouring occurred after first hour. Major change after that appeared in the development of the secondary breaker which appears as a well defined plunging wave on the south side of the tank. Primary breaker is occasionally not breaking entirely across tank.

Figure A-1. Typical laboratory logbook entry.



SURVEY REPORT (INITIAL SHEET)

SURVEY NO. 10 - 25 HRS

SHEET NO. 1 OF 6 SHEETS IN THIS PROFILE

BEACH EVALUATION PROGRAM
COASTAL ENGINEERING RESEARCH CENTER
KINGMAN BLDG., FT. BELVOIR, VA. 22060

10 - FOOT
NAME OF BEACH

R-09
LOCATION (PROFILE OR PROFILE NO., IF AVAILABLE)

LOCALITY CODE (TO BE FILLED IN AT CERC)

PROFILE CODE (TO BE FILLED IN AT CERC)

SURVEY NUMBER

SHEET NUMBER

NO. OF SHEETS IN PROFILE

HOUR

DATUM: MSL, MLW, OTHER

DATE: YEAR; MONTH: JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC; DAY

SURVEY METHOD USED: INSTRUMENT LEVELING, STADIA MEASUREMENT, HAND LEVELING, OTHER (IF OTHER SPECIFY ON REVERSE SIDE)

HAS THERE BEEN ANY CHANGE IN PROFILE BENCH MARK SINCE LAST REPORT? YES

REMARKS? USE REVERSE SIDE YES

DISTANCE (FT)

ELEVATION (FT)

DCF
CHIEF OF PARTY

WOD
FORM FILLED IN BY

CERC FORM NO. 121 - 72
11 May 72

USE NO. 2 PENCIL – ERASE COMPLETELY ALL MARKS YOU WISH TO CHANGE – DO NOT TEAR, FOLD, OR STAPLE

Figure A-2. Optical mark scanning form.

Roll Code LEBS/2N10020A Date 7 July, 1972
Name of study Equillibrium / Reflection
Variable Measured Envelope #19
Tank SPTB : 10-Foot Tanks
Period 3.75s Eccentric 4.20" Depth 2.33'
Type of gage CERC LAB ; Mark 280
Position of gage Center Each Flume : Sta 15-50-15
Gage cal. 750'/50 lines Paper speed 2mm/sec
Sensitivity for: cal. 20mm/line recording 20mm/line
Investigator Schiappa, Brown, Stafford

6AUG69

Roll Code LEBS/2N10020B Date 7 July, 1972
Name of study Equilibrum / Reflection
Variable Measured Envelope #19
Tank SPTB : 10-Foot Tanks
Period 3.75s Eccentric 4.20" Depth 2.33'
Type of gage CERC LAB ; Mark 280
Position of gage R-1, R-9, Sta. 15-50-15
Gage cal. 750'/50 lines Paper speed 2mm/sec
Sensitivity for: cal. 20mm/line recording 20mm/line
Investigator Schiappa, Brown, Stafford

6AUG69

Roll Code LEBS/2N10020A Date 7 JULY, 1972
Name of study Equillibrium / Reflection
Variable Measured Envelope #19
Tank SPTB : 10-Foot Tanks
Period 3.75s Eccentric 4.20" Depth 2.33'
Type of gage CERC Lab; Mark 280
Position of gage Center Each Flume: Sta. 15-50-15
Gage cal. 750'/50 lines Paper speed 2mm/sec
Sensitivity for: cal. 20mm/line recording 20mm/line
Investigator Schiappa, Brown, Stafford

6AUG69

Roll Code LEBS/2N10020B Date 7 JULY, 1972
Name of study Equilibrium / Reflection
Variable Measured Envelope #19
Tank SPTB : 10-Foot Tanks
Period 3.75s Eccentric 4.20" Depth 2.33'
Type of gage CERC Lab; Mark 280
Position of gage R-1, R-9 : Sta. 15-50-15
Gage cal. 750'/50 lines Paper speed 2mm/sec
Sensitivity for: cal. 20mm/line recording 20mm/line
Investigator Schiappa, Brown, Stafford

6AUG69

Figure A-3. Wave record identification labels.

BEST AVAILABLE COPY

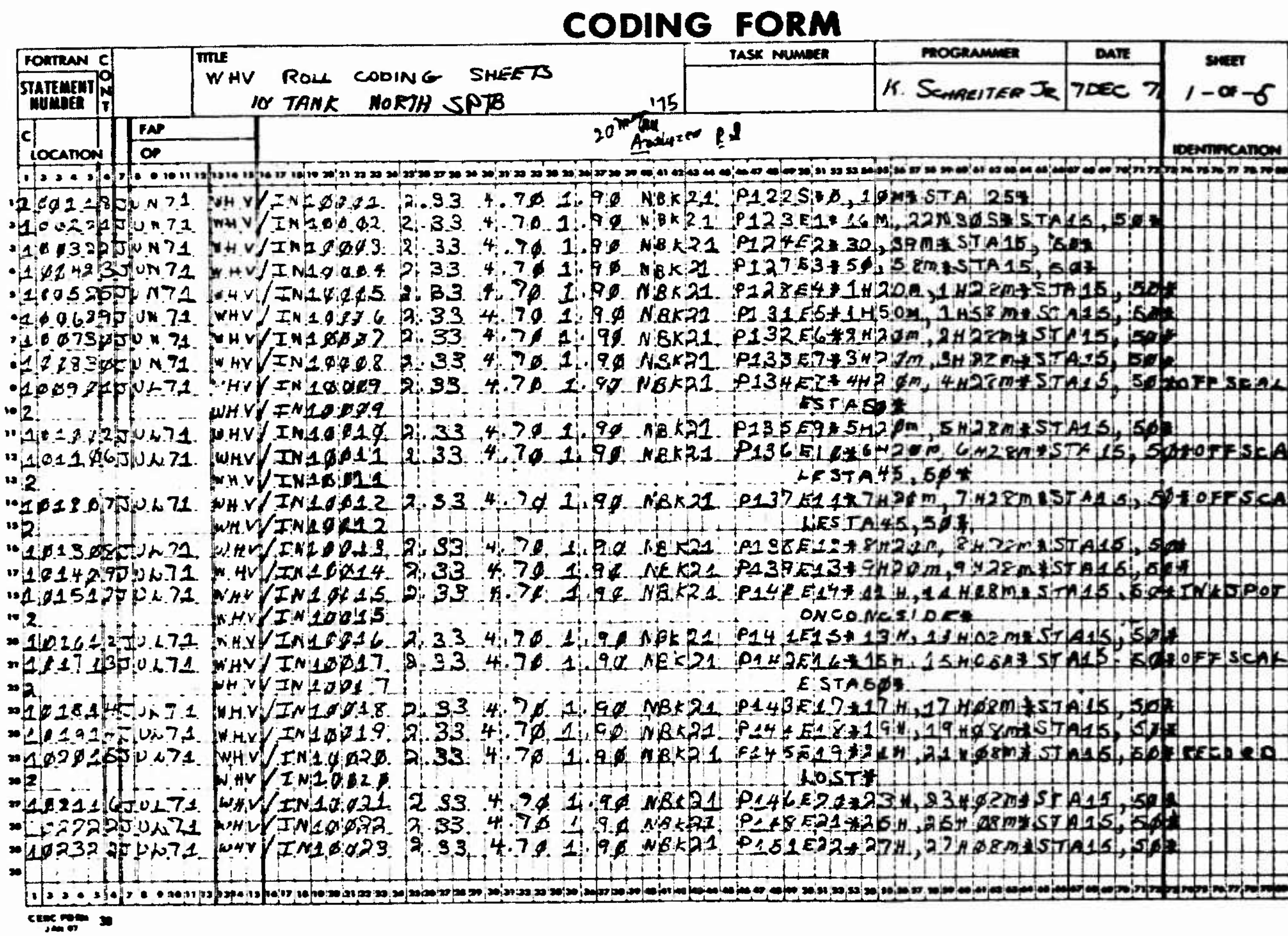


Figure A-4. Wave record lab coding form.

Column	Log Card
25 to 39:	test conditions in form: column 25 to 28: depth in form 02.33 column 29 to 33: stroke in form 04.70 column 34 to 39: period in form 01.92
40:	state of analysis: A = analyzed P = partly analyzed N = not analyzed
41 to 49:	reference to lab notebooks or other sources, such as BK16 P5
50 to 80:	comments in following order (keep the a b c d order and separate each kind of comments by * so that they read a*b*c*d; there should be three *'s somewhere between columns 50 and 80 for each roll): a. type of data b. duration of running time c. station of gages d. other comments

b. Procedure for coding comments in card columns 50 to 80.

a. Type of data: These may be envelopes (E), bursts (B), fixed or stationary gages (F), miscellaneous (M), or stands (S)
E1 indicated envelope 1.
E1, 4 indicates envelopes 1 to 4.
F20 means fixed gage at station 20.

b. Running time: Give the times at start and end of roll (in minutes). Zero minute is the time when first wave started on new beach, or other starting point; e.g., a record beginning after 3 minutes of wave action on a new beach and lasting for 9 minutes will be coded 3, 12M.

c. Location: Indicate location of gage (in feet) from stillwater level by STA.
STA 15, 40 means gage moving from 15 to 40.
STA 15, STA 40 or 15 40 means gage fixed at stations 15 and 40.

d. Other Comments: Abbreviate as much as possible, but be consistent.

Note 1: Entries must be made in the above order. Each roll code must have three asterisks somewhere in card columns 50 through 80. If an item is missing, skip a space.

Note 2: If comments cannot be completed by column 80, go to next card, put 2 in column 1, repeat roll code in columns 17 to 24, and continue comments beginning in column 50 of this second card. Up to 9 cards may be used for one roll code to complete comments.

c. Handling of the wave record log.

After logging and coding the wave records, the cards must be kept in an orderly fashion. The group of cards from each study and each tank must be kept separately; e.g., the group of cards from the secondary wave study in the 96-foot tank is kept separate from the group of cards for the wave height variability study in the 10-foot tank. Both of these are kept separate from the group of cards from the wave height variability study in the 96-foot tank.

Placed in each group of cards are sets of reference cards. Each set has five cards. The first two are blank, the format of the second two are the same as the two cards attached, and the fifth is blank. These reference sets are placed with 56 data cards between them throughout each group so that the reference set appears at the top of each page of the listing printout. This means that cards cannot be added or deleted from the center of a group and that after adding 56 data cards from the last reference set, a new set must be added. When a listing is required, each group must be listed separately so that the reference sets will still appear at the top of each page of the listing and cards can be added at the end of each group without disturbing the other groups.

5. LEBS Photo Log.

In 1971, the example form in Figure A-5 was adopted for uniformity and convenience in recording slide file data. This information was then used when cataloging the slides.

6. Visual Observation Form.

In mid-August 1971, the form in Figure A-6 was adopted to record a series of observations made at the end of each test run. These observations allowed the principal investigators to monitor the beach features on a run-by-run basis for indications of equilibrium.

7. Scarp-Ridge Survey Form.

This form (Fig. A-7) was used to record the station and elevation of particular beach features and was completed after each survey in 1971 and 1972. Unless the scarp and ridge points coincided with a half or full station, these points were passed over in the regular survey.

LEBS PHOTO LOG: SPTB

LOCATION 6-foot Tank
DATE 20 July 1972

PHOTOGRAPHED BY Stafford

FRAME NO.	SUBJECT	TEST TIME
	SWL begin - if slope is damaged	0^H 0^M
17	Initial 1 on 10 slope	
21	Runup near end	0^H 10^M
22	Breaker, end	0^H 10^M
23	SWL, end	0^H 10^M
	Other	
18	Runup, initial (7th - 8th wave)	0^M 20^S
19	Breaker	0^M 30^S
20	Splash-up from breaker	0^M 45^S

Stopped on: 2 Feb. 73 LCT

REMARKS:

Figure A-5. LEBS photo log.

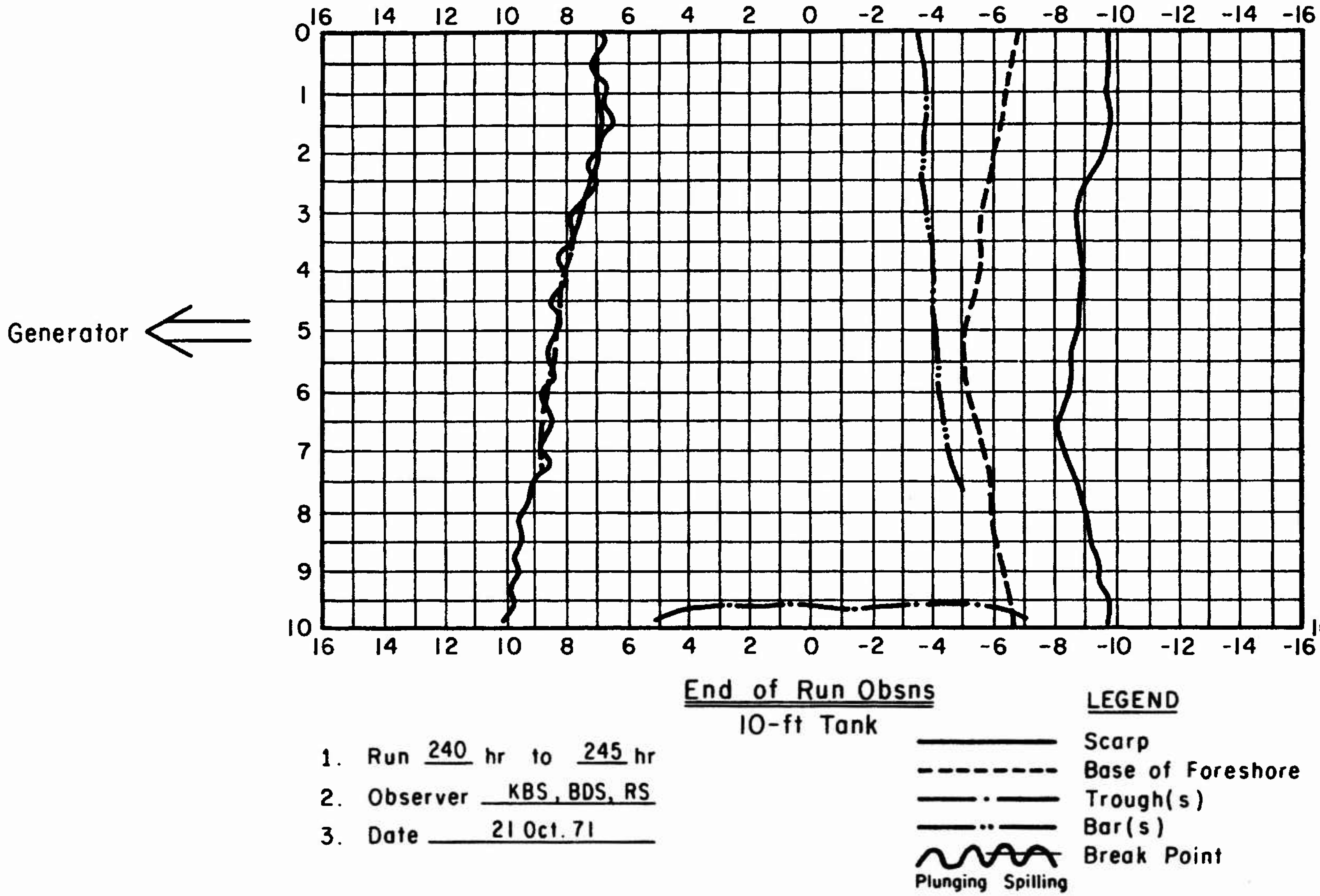


Figure A-6. Visual observation form.

WAVE HEIGHT VARIABILITY
SCARP AND RIDGE
SURVEYS

6-FOOT TANK SURVEY NO. 1

SCARP

RANGE	TOP		BOTTOM	
	Station	Elevation	Station	Elevation
-1	-5.0	2.85	-4.6	2.68
-3	-6.2	2.96	-6.0	2.90
-5				

RIDGE

RANGE	TOP	
	Station	Elevation
-1		
-3	-1.2	2.60
-5	-2.0	2.82

REMARKS:

Figure A-7. Scarp-ridge survey form.

8. Current Study Form.

Current studies were not extensively attempted until 1972. The form in Figure A-8 was used to plot the paths of the current markers.

9. VA Tube Analysis Chart (MRD Form 0640).

The sand-size analysis form (Fig. A-9) was used by the U.S. Army Engineer Division, Missouri River, laboratory with the VA Tube to determine the size distribution of 1972 sand samples.

10. BEB Sediment Analysis Form (C45129).

This is an old Beach Erosion Board (BEB) form (Fig. A-10) still used to tabulate dry sieve analysis data. The form was used for the 1970-72 sand sample analysis when the dry sieve analysis was used.

11. Optical Mark Scanning Form (CERC Form 62-69).

This form (Fig. A-11) was used with the RSA in processing 1970 and 1971 sand samples.

LEBS CURRENT STUDY   Date 16 August 1972

10-foot Tank   Sand   Surface

Run Time: Start 65^{H} 25^{M}

Stop 66^{H} 10^{M}

Observer Mowrey

Legend: x —time in seconds / No. of obns.→   general flow / no time →

Remarks (if more space is needed use back):

Bob #1 dropped R-05 at breaker 0 sec. gully R-02, stayed in uprush 45 min.
Bob #2 dropped R-09 +16, moved into uprush, gully R-02, removed.
Bob #3 dropped R-01 +16, moved into uprush, wind gusts gullies R-01, R-09, removed, strong wind.
Bob #4 dropped R-09 +18, moved into uprush, gullies R-00, R-07.
Bob #5 dropped R-09 +20, moved to +16, +18, +20, +23, and +24 removed.
Bob #4 was removed from uprush after staying 15 min.

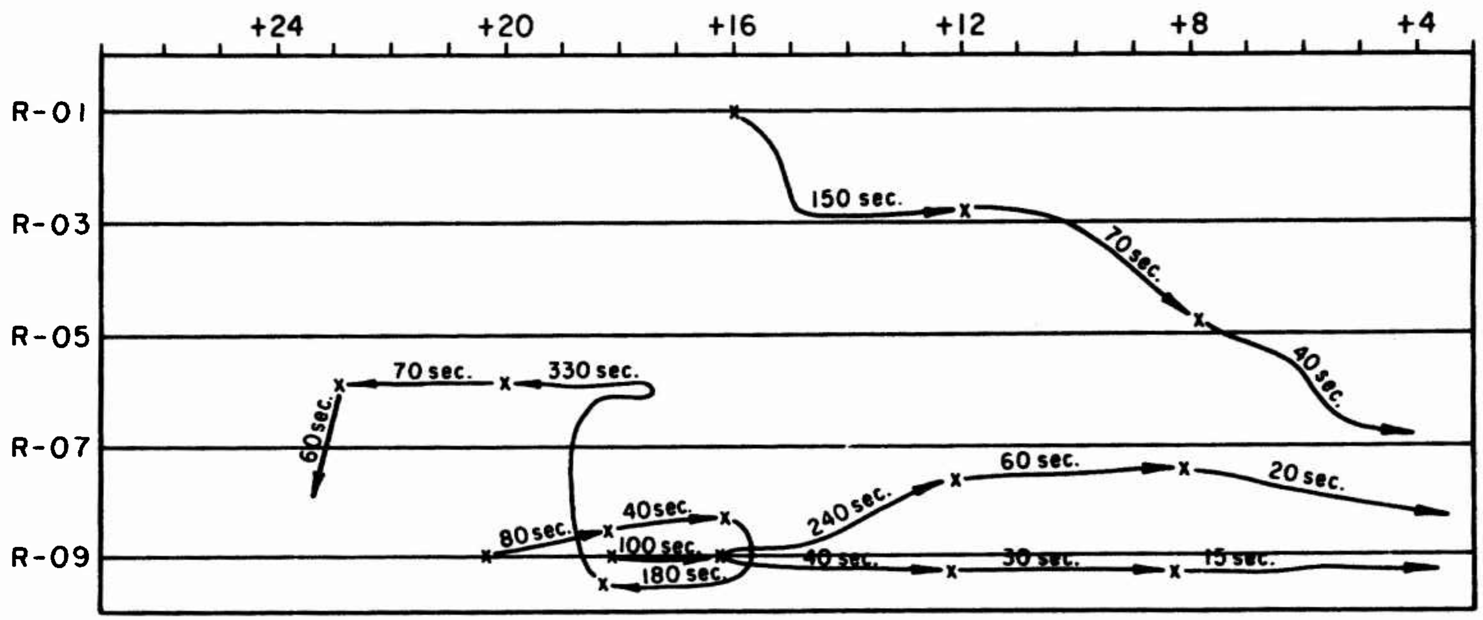


Figure A-8. Current study form.

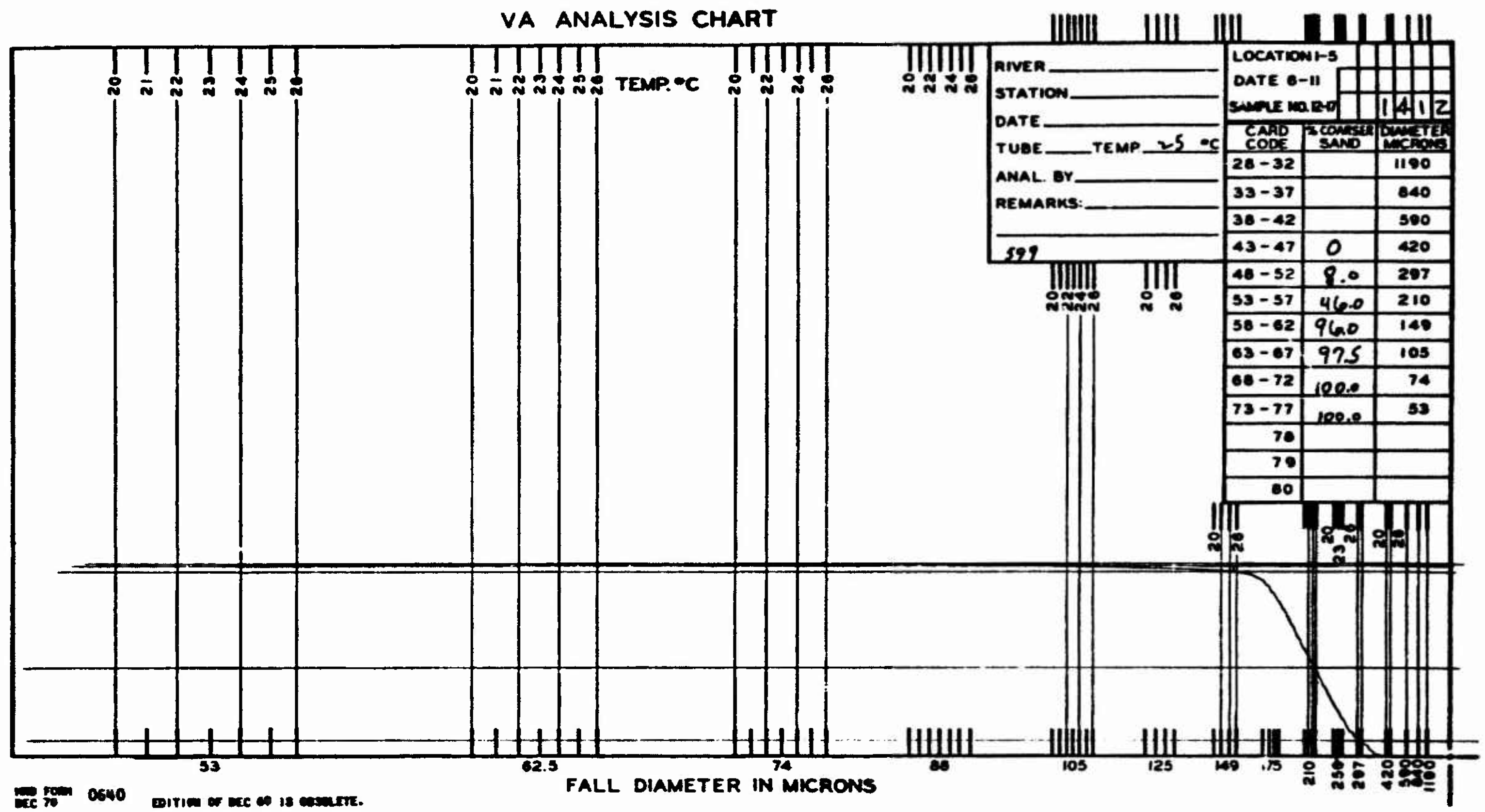


Figure A-9. VA Tube analysis chart.

Analysis No. C-N-1021

BEACH EROSION BOARD-SEDIMENT ANALYSIS

Field sample no. .... Collected by .... Date 12 DEC 72
Project ....
Location 10 Ft Table - 09 - 02 .... 140 # ....
Remarks ....

Weight of sample 40.50 gr. SIEVE ANALYSIS OF SAND Analyzed by F L Date 8-2-73

Screen Opening MM.	U. S. Mesh Number	Retained on sieves		Cumulative Retained on sieves		Cumulative Per cent Passing
		Grams	Per Cent	Grams	Per Cent	
26.670	-					
19.100	-					
9.520	-					
6.350	-					
4.760	4					
4.00	5					
3.360	6					
2.83	7					
2.38	8					
2.00	10					
1.41	14	.00	—	.00	—	
1.00	18	.00	—	.00	—	
.710	25	.00	—	.00	—	
.500	35	.02	.05	.02	.05	99.95
.350	45	.78	1.93	.80	1.98	98.02
.250	60	13.42	33.14	14.22	35.11	64.89
.177	80	22.13	54.64	36.35	89.75	10.25
.125	120	3.79	9.36	40.14	99.11	.89
.088	170	.28	.69	40.42	99.80	.20
0.062	230	.07	.17	40.49	99.96	.04
0.000	Pan	.01	.02	40.50	100.00	.00
Totals		40.50	100.00	40.50	100.00	
Gain or loss		00				

STATISTICAL VALUES
Median diameter .... mm.
Geometric mean diam. .... mm.
Phi standard deviation ....
Effective size .... mm.
Uniformity coefficient ....
Abrams fineness modulus ....
D 25% .... mm. D 75% ...... mm.
Sorting coefficient ....
Sieving time .... min.
Computed by .... Date ....

SPECIFIC GRAVITY
Weight of flask .... gr.
Wt. of flask & sand .... gr.
Weight of sand .... gr.
Wt. flask, sand & water .... gr.
Wt. (volume) of water .... gr. (cc.)
Volume of sand .... cc.
Temperature of water .... °C
Absolute specific gravity .... gr./cc.
Dry specific gravity .... gr./cc.
Analyzed by .... Date ....

SHELL, CLAY, SILT & ORGANIC MATTER ANALYSIS
Weight of empty beaker .... gr.
Weight of filter paper .... gr.
Weight of test sample .... gr.
Wt. b & s. after HCL .... gr.
Weight of sand .... gr.
Wt. silt, clay & org. m. .... gr.
Weight of shell .... gr.

Per cent (%) sand ....
Per cent (%) shell ....
Per cent (%) silt ....
% Clay & organic matter ....
Analyzed by .... Date ....
Remarks ....
C45179

Figure A-10. BEB sediment analysis form.

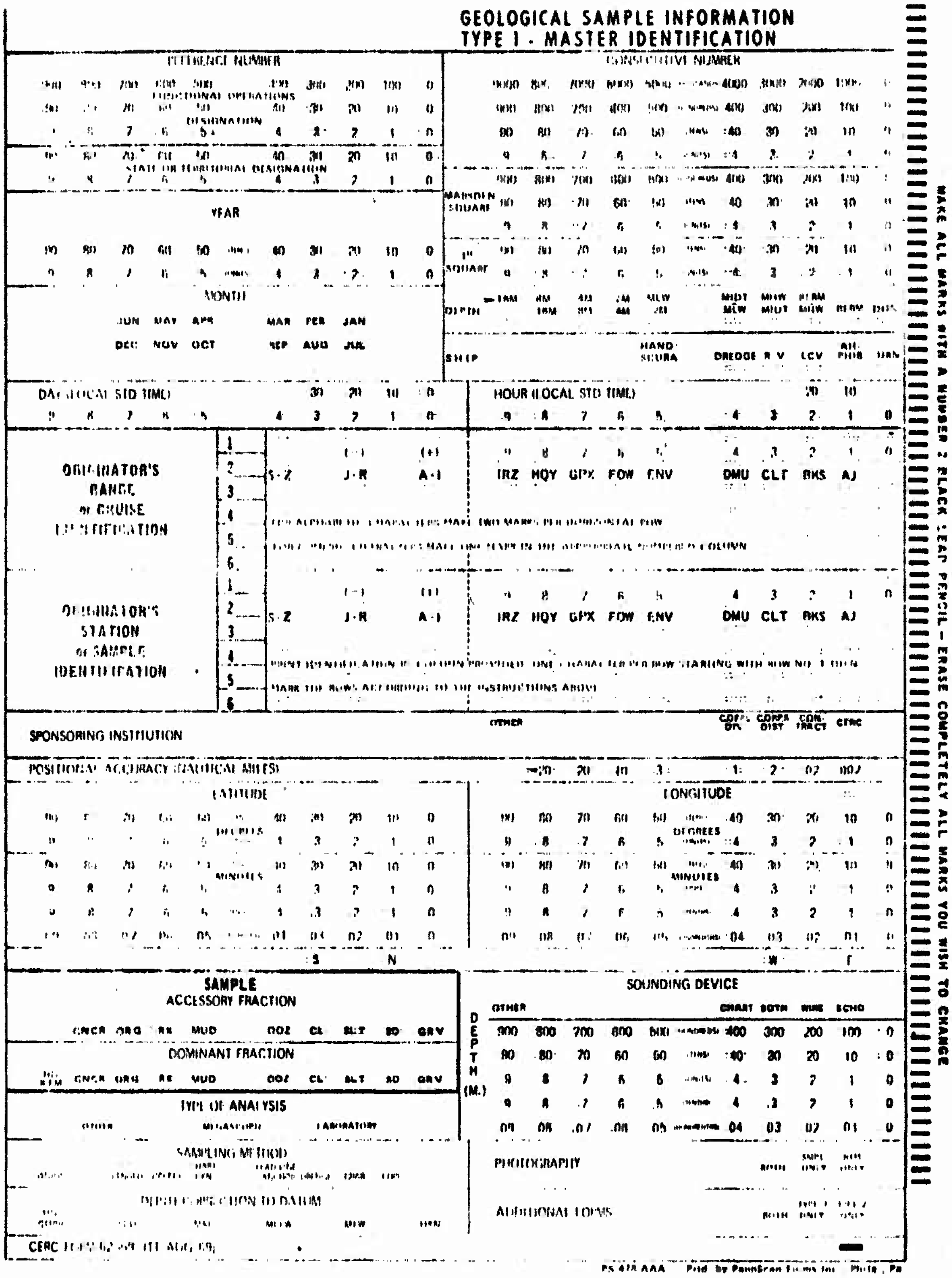


Figure A-11. Optical mark scanning form.

APPENDIX B

FUNCTION OF WAVE GENERATOR COMPONENTS

Section IV gives the major components of the SPTB portable wave generators and the major function of each. This appendix describes the procedure for starting the generators and component interaction.

1. The main a.c. drive motor was started. This caused rotation of some of the differential gears, including those connected to the two d.c. motor armatures. Since these gears were rotated at the same speed, there was no output from the differential at this point.

2. The d.c. rectifier-amplifier was activated by slowly applying voltage through a variable transformer or variac. As this was done, the generator crank arms were observed to determine that the drive shaft of the generator remained stationary, except for perhaps a quarter turn to seek the "lock-in" position. If the shaft rotated more than a quarter turn, the variac was turned down until the rotation stopped. The two thyratron tubes in the amplifier were then balanced by the balancing potentiometer on top of the amplifier chassis. This was done by again raising the voltage while turning the potentiometer clockwise a sufficient amount to prevent rotation of the generator crankshaft. Expertise in this adjustment was achieved largely by experience. The procedure was continued until full voltage was reached.

3. The varidrive was started. This drive had been previously adjusted to rotate at a speed which would cause the generator bulkhead to produce the desired wave period. The speed reference shaft, which was connected to the varidrive, and the generator crankshaft were compelled by electroservo action to rotate at fixed ratios determined by the gear selector box in the wave generator. The rotation of the master resolver, connected to the speed reference shaft, initiated a sequence of electrical events between the two resolvers and the d.c. amplifier, and caused the two d.c. motors to rotate at different speeds. Thus, differential output began, imparting motion through the drive train to the crankshaft and bulkhead. At the same instant that output rotation began, both the slave resolver and d.c. tachometer became activated. As the varidrive and master resolver accelerated, imbalance between the resolvers and the d.c. amplifier continued, and the speed difference of the two d.c. motors increased proportionally with increased varidrive speed until the two resolvers and the amplifier reached a steady-state or in-phase relationship. Provided the generator load capability was not exceeded, the generator would continue to operate "in step" with the control drive mechanism. To assist in maintaining a steady-state condition under varying bulkhead loading, the tachometer supplied a d.c. voltage to the thyratron tubes of the amplifier which caused the tubes to supply more or less power as required. A "phase-shift" signal from a "leading" or "lagging" resolver had the same effect on the tubes, but in a slightly different manner.

Two methods were used to attain the desired wave period by adjusting the speed of the varidrive. The first method was to operate the complete generator system with the basin drained, and adjust the speed of the varidrive until the generator bulkhead motion was set at the proper period. The second method was used when the basin was filled. The transmission gear settings gave a speed reference shaft-to-crankshaft ratio of 3 to 1. Therefore, the varidrive could be adjusted to the proper speed using the speed reference shaft (60 revolutions per 38 seconds for the 1.90-second period), while the generator blade could be left stationary by not turning on the a.c. motor and amplifier. The first method was preferred because the entire system could be checked out before starting the experiment.

APPENDIX C

AUTOMATED DATA REDUCTION OF REFLECTION COEFFICIENT

The steps in the automated data reduction of reflection coefficients using programs WVHTCN and WVHTC2 are given below. The programs are described in Section V.

1. Digitizing.

The data on the wave records are digitized by CERDP, producing sets of x and y points for each crest, trough, and event mark on each envelope. These points are recorded on tape and then punched on cards.

2. WVHTCN Program.

The WVHTCN input for each envelope consists of three sections of cards: crests, troughs, and event marks. Each section begins with a card containing the test label in columns 1 to 15 and ends with a card containing 80 periods. At the front of the envelope data deck is a card with the envelope identification number in columns 21 to 35. Any number of wave envelopes may be run at one time. If an end-of-file is to be written on the tape, the last card of the data deck must have "ENDEND" starting in column 21. Output for each envelope includes a printout of the data for editing, a plot, and a tape for input to WVHTC2.

3. Estimating Amplitude and Phase Angle of Sine Curve.

Before running WVHTC2, a first estimate of the amplitude and phase angle for the best fit sine curve is determined from the WVHTCN plots. A sine curve with the appropriate wavelength is drawn and placed over the WVHTCN plot. The sine curve is adjusted until it fits the plotted curve most closely. Then the points on the plotted curve coinciding with the crests and troughs of the sine curve are measured and averaged to determine the first estimate of the amplitude. The first estimate of the phase angle (between -180° and +180°) is found by measuring from the origin of the graph to the nearest point where the sine curve crosses the positive or negative x-axis. This value divided by one-half the wavelength of the sine curve and multiplied by π gives the phase angle in radians.

4. WVHTC2 Program.

When running program WVHTC2, A1 = amplitude (F5.2, col. 16); A2 = wave number (2/L), (F5.2, col. 21); A3 = phase angle (F5.2, col. 26); and XXX = the part of the envelope to be plotted (2F5.2, cols. 36 and 41). The limits of the envelope to be fitted are given in inches with a scale of 1 inch equals 5 feet. Time (F5.1, col. 31) is in hours and tenths of an hour. All variables are right-justified when punched into the card. The roll code number is punched in columns 1 to 11 and the envelope number is punched in column 13. One card is punched with this information

for each wave envelope. The number of envelopes to be plotted is punched right-justified in columns 1 to 5 of another card and placed at the front of the data check.

The plots generated by WVHTC2 give wave height deviation from the local mean with the best fit sine curve superposed.

5. Determining K_R.

K_R is determined from the plot by dividing the amplitude of the sine curve by Y_{AVG}. Both values are written in the plot heading.

Stafford, Robert P.
Laboratory effects in beach studies. Volume I. Procedures used in 10 movable-bed experiments / by Robert P. Stafford and Charles B. Chesnutt. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center, 1977.
67 p. : ill. (Miscellaneous report – U.S. Coastal Engineering Research Center ; 77-7)
Bibliography: p. 47.
This first volume of an eight-volume series describes the experimental procedures used and the wave and beach conditions existing during 10 long-duration, movable-bed experiments. This volume also serves as a procedural manual for coastal engineering experiments, and describes CERC's portable wave generators.
1. Coastal engineering. 2. Breakers. 3. Currents. 4. Movable beds - Models. 5. Wave generators. 6. Wave reflection. 7. Wave tanks. I. Title. II. Chesnutt, Charles B., joint author. III. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 77-7.
TC203 .U581mr no. 77-7 627

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